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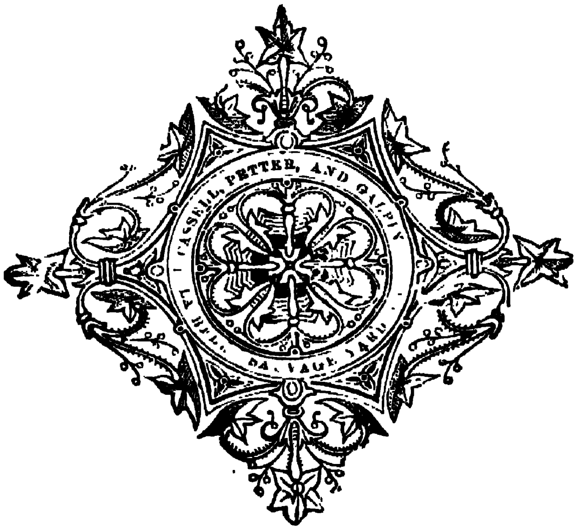
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THE TECHNICAL EDUCATOR:

BEING THE TECHNICAL SERIES OF "CASSELL'S POPULAR EDUCATOR."

MINING AND QUARRYING.—I.

By George Gladstone, F.C.S.

DISTRIBUTION OF THE MOST USEFUL MINERAL PRODUCTS—NATURE OF BEDS AND LODES—IMPORTANCE OF STUDY OF GEOLOGY.

To the inhabitants of the British Islands there is no industry that will compare in importance with that founded upon the substances which lie below the surface of the ground. Two articles—coal and iron—form the very groundwork of our national prosperity, but there are many others which are also worthy to be ranked as of first-class importance. Cornwall and Devonshire supply nearly all the tin ore raised in Europe. The slates of North Wales have a world-wide reputation. The salt-mines of Cheshire and Worcestershire enjoy advantages over their Continental rivals in respect of their proximity to shipping ports, which greatly add to their commercial value. In the succeeding papers, which purpose to include not merely the ores of the metals, but the other mineral substances which are made to contribute to man's comfort, it will become evident that these islands are, in proportion to their size, singularly rich in these articles.

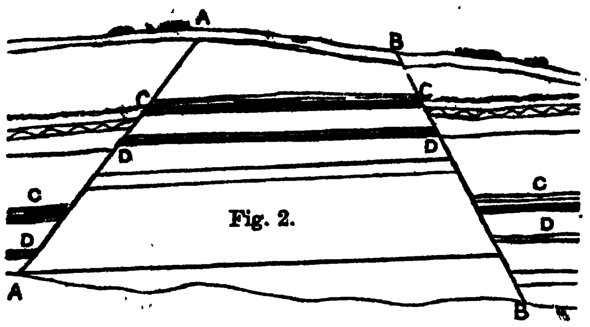

Fig. 2.

This might indeed be inferred from the fact that within the comparatively limited area of the United Kingdom almost all the important geological formations, from the newest tertiary to the oldest primary schists, are represented, and that in many places these have been upturned and pierced by eruptive rocks. The undulating or hilly surface, by which this country is distinguished from many others, is the effect of geologic disturbances which are highly beneficial to man. A level country is seldom rich in its mineral productions.

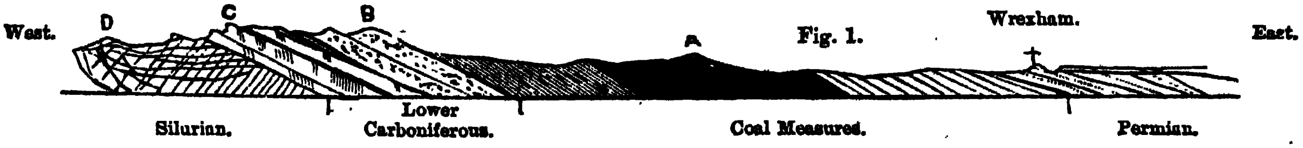

Fig. 1.

Let us take in order some of the principal groups of strata, commencing with the newest, and see what useful substances they contain.

Tertiaries	Brick clays, pipe-clay, septaria or cement stones, gypsum, coprolite, sand.
Cretaceous	Lime, brick clays, flints, fuller's earth.
Wealden	Sand for glass works; clays.
Oolites Lias	Iron ores, alum shales, jet, cement stone, lime, clays, building stone.
Trias Permian	Salt, gypsum, brick clays, building stone.
Carboniferous	Coal, limestone, fire-clay, oil shales, lime, sandstone, marbles, zinc, lead, silver, baryta.
Devonian	Tin, copper, sulphur ores, flag stones.
Silurian	Lime, lead, copper.
Cambrian	Slate, zinc, lead, copper.

In addition to these there are the eruptive rocks, such as granite and serpentine, which furnish excellent building and ornamental stones. Some particular kinds of the former, which readily decompose on exposure to the air, furnish kaoline, of which the finest china is made.

Now, if these various rocks were all to lie conformably one upon another, as in the foregoing list, the country would present the appearance of a plain, and the lower strata would be so far below the surface as to be practically unapproachable. The temperature of the earth increases at the rate of one degree Fahrenheit for about every fifty-five feet in depth; so that the increase of heat will infallibly prevent men from working below a certain depth; some of the tin mines in Cornwall are indeed carried almost to their extreme limit in this respect, the temperature being so high to render the mining operations very exhaustive.

The effect of the rise in temperature may be readily calculated. The first 100 feet from the surface are more or less subject to the changes of the seasons; but at about that point the temperature is uniform all the year round, and agrees with the mean temperature of the surface. Let us take that, therefore, at 50° Fahr. From that point downwards the increase is 1° for every 55 feet; so that at 1,650 feet from this point, or 1,750 feet from the surface, we shall have an addition to the temperature of 30°, making the temperature at that depth 80° Fahr. This measurement bears [illegible] small proportion to the thickness of the sedimentary strata composing the crust of the earth, which, if they occurred in a complete series, would, it is estimated, extend to a depth of 14 miles, or 73,920 feet.

But this regularity scarcely ever happens in Nature; and there is no ground for the assertion that in any one particular spot all the known rocks are present, though of those which do occur the order of superposition is invariable. The Wealden and Trias, for instance, may be wanting in one place, the Cretaceous rocks in another, or they may be only very slightly developed; but the Cretaceous will never be found below the Oolite, or the Silurian above the Carboniferous. The various upheavals and subsidences which the crust of the earth has suffered, and which are represented by the hills and valleys, together with the subsequent denudation of the upturned edges, afford the opportunity of seeing at the surface in different parts of the country all the various strata, down to the very lowest of the series. Thus, for instance, in the annexed diagram (Fig. 1), which represents a section across the Denbighshire coal-field, about six miles in length, it will be seen that Wrexham stands upon the Permian rocks, that at A the coal beds crop out at the surface, while at B the millstone grit, at C the mountain limestone, and at D the Silurian rocks are exposed. At A, therefore, the miner can raise his coals at or near the surface; and even at Wrexham, by a calculation of the angle at which the coal measures dip to the eastward, he can estimate with tolerable accuracy the depth to which he would have to sink through the Permian rocks and the upper coal measures, before reaching the same beds of coals as are found at A.

Such articles as coal, which always lie in seams or beds parallel to the plane of stratification, can thus be readily traced through considerable tracts of country with a greater or less degree of certainty. These calculations are liable, however, to be disturbed by faults, which are breaks in the continuity of the strata through some local disturbance, by which the seam may be suddenly raised above or depressed below its proper level. These are not unfrequent, and often cause great trouble and expense to the proprietors of the colliery. Fig. 2 will serve as an illustration of a double one. A A and B B are the lines of fault by which the continuity of the seams of coal, C C and D D, has been abruptly broken in two places. The displaced portion in this instance is raised above its proper level, and this would therefore be termed an *upcast fault*. A displacement in the opposite direction would be a *downcast*. Sometimes a fault occurs singly, whereas in other districts a succession of them, some up and some downcast, will be met with, breaking up the coal bed to such an extent as to prevent its being profitably worked. The surface ground often furnishes, as in the drawing, little indication of the faulty character of the rock below, the portion which has been thrown up being more liable to denudation than the surrounding country; and in like manner the depression in the case of a downcast fault is apt to get filled up.

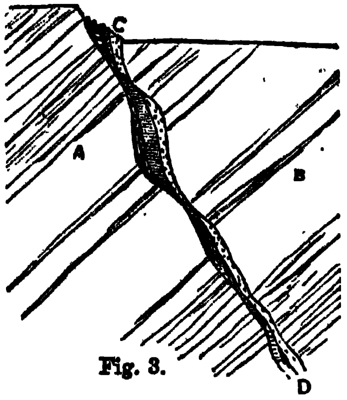

Fig. 3.

The ores of the metals, iron excepted, are not generally to be found in beds conformable to the stratification, but in what are termed *lodes* or *veins*. The former term is more commonly applied to the larger, and the latter to the smaller. A lode may be described as a long, narrow cleft extending through the rock from the surface downwards, in general at an angle not very far from the perpendicular, and usually taking a course somewhere near east and west. These are frequently intersected by others running nearly north and south, cutting the former, therefore, at about a right angle, which are termed *cross courses;* they are seldom so rich in mineral as the east and west lodes.

Just as in the faults which occur in the coal-fields, the lode is often accompanied by a change in the level of the rock through which it passes. Thus in the diagram (Fig. 3) the stratification on the side B will be seen to lie lower than that at A, and the fissure C D not being straight the lode is necessarily of very unequal breadth, the curves of the walls of the lode corresponding pretty closely, though thrown out of position. This is by no means an unusual occurrence, and it accounts for the great changes which frequently take place in the size of lodes in mines. The form of the fissure often greatly affects also the mineral contents. In mining language, the rock on the side A would be called the *standing wall*, and that at B the *hanging wall* of the lode.

The formation of the fissures in which the ore is deposited seems to be generally due to disturbances in the earth's crust, caused by the extrusion of some igneous rocks from below; the majority of such lodes being in the neighbourhood of masses of granite or other eruptive rocks, or where the sedimentary deposits have been much metamorphosed by subterranean heat. The processes in Nature's laboratory that have caused the clefts so made to be filled with mineral matter cannot be satisfactorily made out, as a similar result cannot be produced by artificial means. The igneous rocks themselves do not contain the metal, though the richest mines in England are those situated at the very junction of the granite with the clay slates of Cornwall.

Slate and building stone generally occur in much greater masses than either coal or the ores of the metals, and they are on that account rather quarried than mined, the workings being usually open to the light of day. Such slate, however, as is sufficiently good in quality for the purposes of trade does run in veins, and some of these lie at such an inclination, and penetrate so far into the bowels of the mountain, that open workings become impossible, and then the operations resemble much more those of the miner.

The value of slate is due to a peculiarity in certain of the older rocks—and especially the argillaceous beds of the Cambrian series—which is termed *cleavage*. In order to explain this novel feature let us take Fig. 4, which may be supposed to represent a gigantic block cut out of the mountain mass. The parallel lines A A, B B, C C, etc., will represent the stratification of the beds, a feature common to every sedimentary rock; but in addition to these we find here another regular series of divisions cutting them at a considerable angle, represented by the lines D D D, E E, etc., which represent the plane of cleavage. It is not merely at the intervals indicated in the drawing that the rock is thus affected, but the whole mass is liable at any point to split in a plane parallel to the cleavage, so that it can be divided into slabs of any desired thickness. It is remarkable, too, that the angle of cleavage remains constant through extensive districts, although the strata within the same range may be subject to great contortions. The cause of this change in the aggregation of the particles of which the rock is composed is very obscure, though it seems most probable that it may be due to heat or pressure, or both combined, especially as in many cases almost all traces of the original stratification have been lost.

In the course of the succeeding articles, these geological features, which so greatly affect the operations of the miner or quarryman, will have to be treated in more detail. But before closing these general remarks it may be well to point out more fully how important is a knowledge of the rudiments of geology, as well as mineralogy, to all those who seek for wealth below the surface of the ground. Were the authenticated instances, unfortunately, not too common, it would scarcely be believed what fortunes have been wasted in a fruitless search after minerals in places where it is impossible they could be found.

Bearing in mind the order of succession of the sedimentary rocks, we may illustrate this point by referring again to Fig. 1. The beds of coal in the Denbighshire coal-field lie in that part of the coal measures which is shaded the darkest, and they crop out at the surface at the part marked with the letter A. The dip is seen by the section to be towards the east. A comparatively shallow pit will cut the coal anywhere between A and Wrexham, though at the latter point the Permian rock would first have to be passed through. But if another adventurer were to sink a pit at any equal distance to the west of A—say at either B, C, or D, it is perfectly certain he would meet with no coal at all, however deep he might carry his explorations. He has begun at a point geologically below the coal, and every fathom he sinks is just so much further from the object of his search.

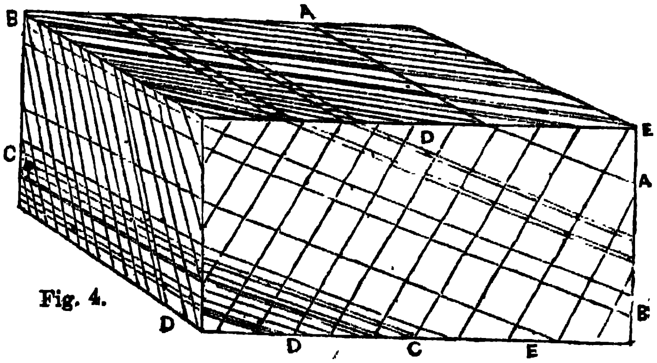

Fig. 4.

Some of the more recent strata contain thin layers of an impure coal, rarely in this country of any commercial value. These have often led to the sinking of pits, under the supposition that the true coal would be found, though a study of the dip of the neighbouring strata would show that the Carboniferous rocks must be so far below the surface as to be practically unapproachable. Thus there are borings for coal and deserted shafts to be found in many parts of the country; at Wincanton and Kingsthorp in the oolite, at Lyme Regis in the lias; at Tiverton in the millstone grit, and in Herefordshire in the mountain limestone; both rocks belonging to the Carboniferous system, but invariably below the coal, as seen at B and C in Fig. 1. At several spots in Wales these attempts have been made in the Silurian, p ; and at Bewdley a shaft has been sunk in the Devonian, which is also lower in the series.

Nor is it in respect of coal alone that such mistakes have occurred. In Cornwall some of the most valuable ores of copper used formerly to be thrown away as rubbish, the inferior ores only being recognised by the miner. In other parts of the country zinc-blende has been wrought, while the calamine, a very rich ore, has been entirely neglected. Iron pyrites has often been mistaken for gold. Thus, in one way or another, valuable produce has been lost, or money has been wasted in fruitless explorations.

In considering the mineral products, and the methods of treating them, more in detail in the subsequent articles, it will often become evident how greatly their value has increased through improvements in the mining and metallurgic arts, and that many have been added to the list of valuable minerals, the worth of which was unknown before.

OBJECT DRAWING.—I.

INTRODUCTION.

In presenting these lessons to the public, it is necessary to define their position in our series of Technical Lessons, and to set forth the purpose they are intended to accomplish.

The course, then, is designed to teach the elements of drawing as a useful language, to elucidate principles which are of such general use that by their application the student may be enabled to draw, not only the subject of the lesson, but numerous others of a similar character.

A further purpose of the lessons is to encourage drawing from the object instead of from copies. We are, of course, aware that beginners must necessarily copy drawings or prints; that copying is an indispensable branch of the study, as by its means practice is obtained in execution and design; and that from imitating the work of others, the student acquires experience in drawing and manipulation.

But these are only the means—not the result. When we teach our children common writing, and expect them to imitate the exact forms of the letters, it is never intended that the end and aim of their lessons shall be merely to copy other writing. We aim at giving them a knowledge of forms, by which words, the visible symbols of thoughts, may be expressed; and thus it will be clear that no system can be a true one which teaches copying only, without affording the necessary practice in drawing from the real subjects.

This course of object drawing must not, however, be supposed to compete with, or to take the place of, perspective proper. It is intended to be studied either before, or concurrently with, that subject, and it is believed that the system here laid down may interest students in the more severe course—that it may cause them to feel the want of accurate rules, in many instances where drawing by the eye must depend on judgment only; whilst the endless variety which object drawing affords must be a source of continuous pleasure to all.

To those who have already acquired some knowledge of Practical Perspective, the study of Object Drawing will be found exceedingly useful, since by its means the scientific methods previously acquired may be applied, and they will be able in a bold and rapid manner to give correct representations of things around them, in the same manner that a knowledge of the rules of grammar enables them to give a well-worded written description.

In order to make the course of lessons as complete in itself as possible, enough of the geometrical figures are given to enable students to construct the true forms with correctness; some of the elementary rules of perspective are also repeated in order to show their immediate application, and to explain how the appearance of objects becomes changed by their position in relation to the spectator. Perfection, then, in object drawing can only come from careful training in Geometry and Perspective; and any teaching which separates it from these, or implies that it is independent of them, is empirical. For the further working out of the rules thus briefly given the student is referred to the lessons on Perspective.

In order to enable teachers to carry out the system here laid down, a set of models has been specially arranged. They are designed not only to serve for separate studies, but may be combined and grouped in an almost endless manner, whilst their size is such as to render them useful in classes, enabling each student to make his observations as to form, light, and shade from his own point of view.*

Teachers are recommended to work out a simple perspective rendering of a model or group on the black-board; and in a subsequent lesson to set up the subject in a different position, to be drawn by the eye alone. This plan, since it shows the students the absolute importance of perspective, will increase the interest and enhance the value of such lessons.

The use of models may be further extended by the constant introduction of well-known objects, such as articles of household furniture, or domestic utensils, agricultural implements, and tools of every kind as subjects of study. Subsequently the pupils should be called upon to draw from memory, not only the subjects of recent lessons, but any they may have seen. The author has been enabled, in fact, by teaching the proper use of drawing, in even junior classes, to write a brief narrative on the black-board, and placing a dash under the leading nouns, to call on the pupils to draw them from memory—or, more properly, from imagination—and has found the plan so very successful that he advises teachers, with the greatest confidence, to adopt it, as not only is the knowledge possessed by the pupils drawn out, but habits of observation and study are cultivated and encouraged.

With the view of aiding students who may not have the use of sets of models, or who may not have the opportunity of making them of wood, patterns will be given from which the most important of the series may be made of cardboard. This in itself will be found good practice in the study of development.

Thus, then, we are enabled to add another contribution to our series of Technical lessons. Our earnest endeavour has been to make the instruction clear and simple, and in proportion to the success attained will be our gratification.

OF THE PRINCIPLES WHICH GUIDE DRAWING FROM OBJECTS.

Although we know that an object has in reality but one form, yet it will not seem the same to persons standing in different places, but its outline will vary with every movement of the beholder. This is called its "perspective appearance," and as this is subject to constant changes, it is clear that, in addition to knowing the exact form, we must study the causes of the alterations in appearance resulting from the different positions of the object, or from the relative place of the spectator.

It is not intended here to burden the mind of the student with a number of rules, such being fully elucidated in our "Lessons on Perspective;" and therefore only such as are absolutely necessary to enable the beginner to sketch from simple objects in a correct manner will be given.

We have, in our first lesson on Perspective, stated that "the moment we open our eyes a flood of light enters, and the rays which pass from the surfaces of every object are thus conveyed by the eye to the brain."

Since, then, we see objects by means of light, it will be clear that if the rays did not proceed from every part of such surfaces, we should see some portions and not others; and further, if the rays were not reflected in every direction, the object would be visible to *some*, but not to all the persons present.

Now it is evident that if a cube were placed in the middle of a room, and the students were seated around, *all* would see it; each might behold different sides, but every one would obtain *some* view of the object. Again, if students were located in a gallery formed after the fashion of a flight of steps, and a cube were suspended midway between the ceiling and the floor, those on the lower steps would see the bottom of the object, those on the middle steps the front only, whilst the spectators on the highest seats would see the top.

From this knowledge, then, which will be clear to all, we deduce the following principles :—

1. *Objects are seen by means of rays of light which proceed in straight lines, in every direction, and from every part of their visible surfaces.*

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* "Ellis A. Davidson's Technical Drawing Models." Cassell, Petter, and Galpin.

2. *The view obtained of an object depends on the position of a spectator.*

If the eye be above the object, the top will be seen; if below, the bottom; whilst the left or right side will become visible according to circumstances.

The first consideration must be the height of the spectator in relation to the object. Let the student, then, ask himself, "Is my eye higher or lower than the object?" This will, of course, be at once evident. He should then consider, "If my eye *is* higher than the object, *how much* higher is it?" and this will lead us to the following principle:—

The horizontal line represents the level of the eye of the spectator in relation to the object.

Therefore, if an object be placed above the horizontal line, we see the bottom, and if above, the top of it; and the view will vary according to the height of the eye.

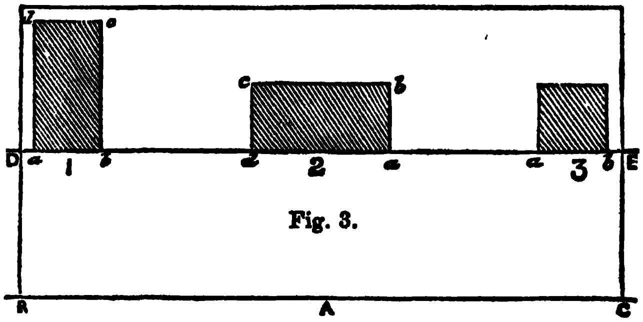

Fig. 3.

But the knowledge as to height will not in itself be sufficient; we must be clear as to whether we see the left or right side; and this brings us to the consideration of the point of sight.

The point of sight, or centre of vision, is the point in the horizontal line which is directly opposite to the eye of the spectator.

We now proceed to show the use of these principles, at the same time urging the student not to be content with the illustrations here given, but to observe their application to all the objects by which he is surrounded.

Let the rectangle A B C D (Fig. 1) represent the general form of the front of a case of shelves, and let E F be the horizontal line. It will then be clear that the object to be represented is twice as high as the eye of the spectator, since the horizontal is drawn across the middle of the height.

The spectator is supposed to be situated on the right side of the object, opposite to PS, which indicates the *point of sight.* It will be evident, that whilst the horizontal edges of the case, A D and B C, which form the top and bottom of the front, and also those corresponding with them at the back, are *parallel* to the picture, the lines of the other edges are at right angles to A D and B C, and consequently at right angles also to the picture. To render these correctly, it is required to understand the following rule:—

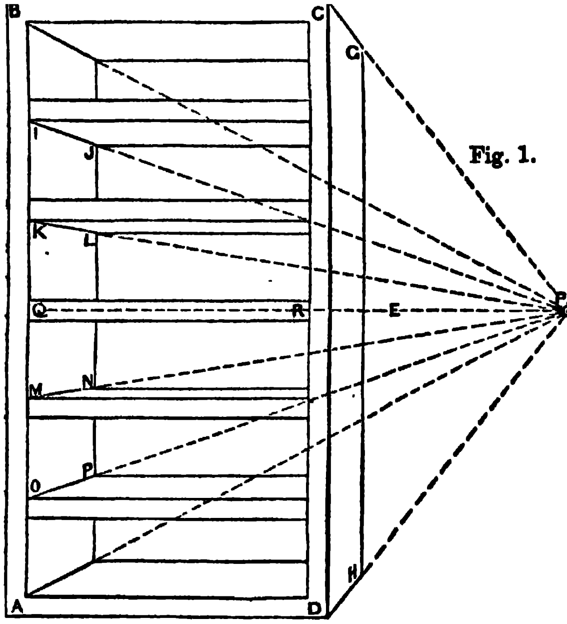

Fig. 1.

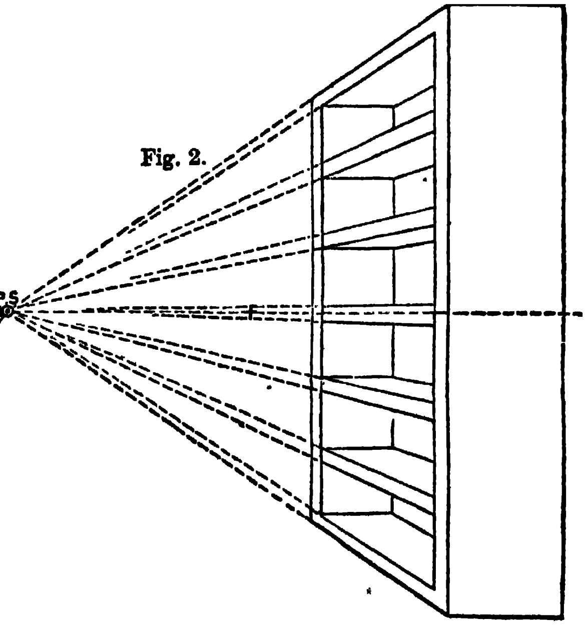

Fig. 2.

All lines which in the object are at right angles to the plane of the picture—that is, such as run directly from the spectator to the distance—must be drawn to the point of sight.

This rule will at once give the direction in which the lines C G and D H are to be drawn; and it will be evident that the narrow ends of the shelves, I J, K L, M N, O P, being in the object parallel to the narrow end of the top and bottom, will converge to the point of sight.

Now, on referring to the illustration, it will be seen that whilst the lines representing the ends of the shelves which are below the horizontal line—viz., M N and O P—are drawn upwards to the point of sight, those which are above (I J, K L) are drawn downwards; thus we see the upper surface of those below, and the underneath surface of those above; and of the shelf which is on a level with the horizontal line—viz., Q R—we see the edge only, neither the upper nor the under side being visible.

Fig. 2 shows the same object when placed on the right side of the spectator, the front of the case being at right angles to the plane of the picture.

Let us now proceed to the practical application of the principles thus far laid down. We will, in the first case, suppose you sitting at a table, the edge of which is parallel to your chest. Let the figure here drawn (Fig. 3) represent the top of the table, and let your position be at A. Now on the opposite side of the table are three equal blocks which are square at their ends, and doubly as long as they are thick.

The artisans to whom these lessons are principally addressed will have no difficulty in providing themselves with three such blocks, which may be of wood, stone, or plaster of Paris, etc. A very convenient size is four inches square by eight inches long; but, of course, the principles about to be explained would apply to objects of any size or proportions: for drawing purposes, however, the blocks should not be smaller than these.

Place a model (1, in Fig. 3) on one of its long faces, with its square end parallel to the edge of the table, B C. All its long edges, as *a d* and *b c*, will then recede at right angles to the square end which stands on *a b*. Place another block (2) so that whilst resting upon one of its long sides, another is vertical, and parallel to B C; and, finally, place the third block (3) on its end, so that the long face in the front, and the other at the back, may be *upright*, and parallel to B C. You will, of course, remember that the rectangles 1, 2, 3 in Fig. 3 are called the *plans* of the objects.

We will in our next lesson attempt, guided by the above figure, to draw these models, as they appear to you from the position in which you are placed.

BUILDING CONSTRUCTION.—XIV.

JOINTS IN TIMBER (*continued*).

FIG. 125 shows another method by which timbers are "notched" on to each other. This is a very good system, for the upper holds as it were by a hook, which acts against a shoulder in the lower. The upper is thus prevented being drawn inward by weight placed upon it, and the lower is strengthened against any pressure which might tend to force it outward.

Fig. 126 is a joint of a similar character, a dovetail being employed in this case, which in Fig. 127 is further secured by an additional shoulder.

Figs. 128 and 129 are methods by which the ends of timbers are firmly attached to beams or wall-plates on which they rest.

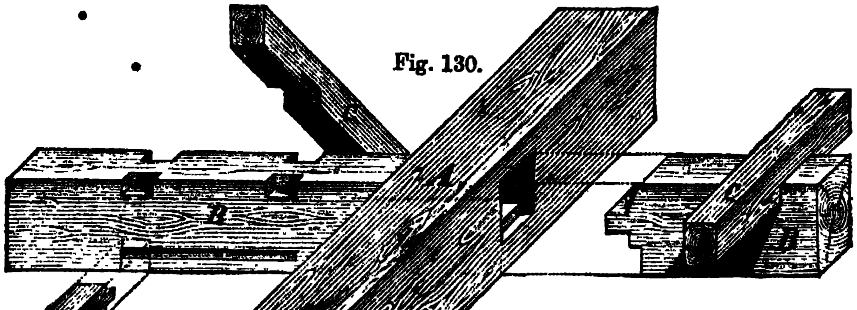

Fig. 130.

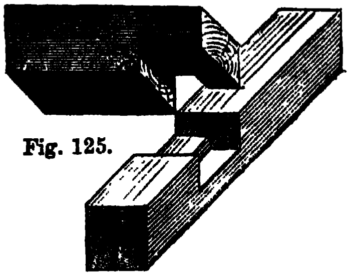
Fig. 125.

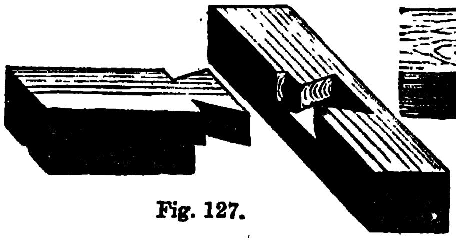
Fig. 127.

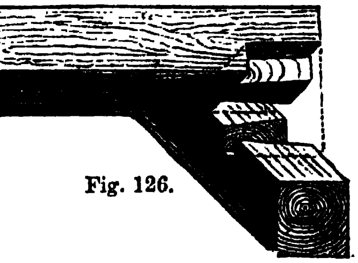
Fig. 126.

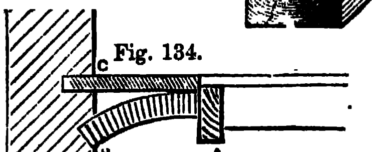

Fig. 134.

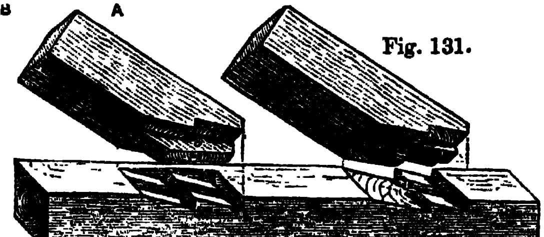
Fig. 131.

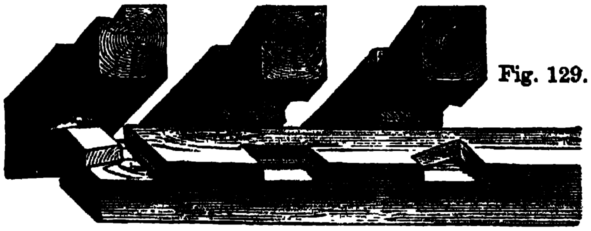
Fig. 129.

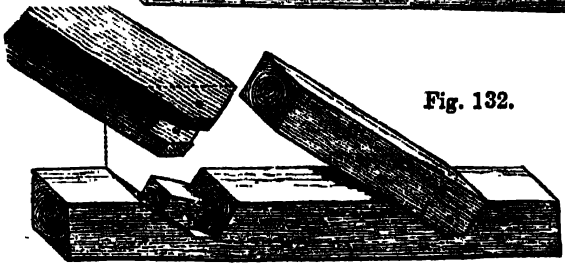
Fig. 132.

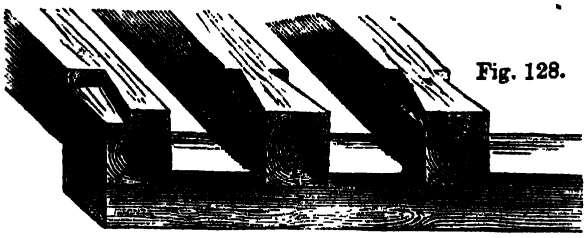
Fig. 128.

The upper surfaces are shown as cut for the reception of an upper timber to further bind them together.

Fig. 130 is the Continental mode of constructing framed flooring, and is here introduced in order to compare it with our system, which is explained and illustrated on the following page. Here A is the girder, B B the bridging-joists, and C the floor-joists.

In this example it will be seen that the ceiling-joist, D, is not notched on the under surface of the binders, but is inserted by a tenon and groove. The groove or slot being made longer than required, the ceiling-joist is placed slantingly across between two binders, its ends being in the opposite ends of the grooves; and by being struck sharply and sufficiently with the mallet it is forced into its proper direction at right angles to the binding-joists.

Figs. 131 and 132 show four different kinds of oblique mortises. The principles on which such joints are worked have already been described.

THE CONSTRUCTION OF FLOORS.

The assemblage of timbers by which floors are supported is called the "naked flooring," and is of three sorts—single, double, and framed.

Single Flooring consists of one row or tier of joists, bearing from one wall or partition to another without any additional support. On these rests the flooring boards, and to their lower edge is attached the ceiling of the room below (if there be any), either by means of laths or ceiling-joists.* These floor-joists rest upon a wall-plate built into the wall; the brickwork of the wall should not quite touch the end of the joist, but should leave a small space all around the end; this prevents any damp in the wall from spreading into the timber, and allows of a certain play of air around it. In better work, however, the ends of the joists are gathered by wooden end-ties and iron tie-rods. These are drawn up by nuts, the joists being meanwhile shored up in the middle, so that when this support is removed the joists may be stiffly braced. Another plan is to rest the wall-plate on projecting corbels, by which means the ends of the joists do not enter the walls at all; and thus any fracture, such as might arise from shaking, crowding, dancing, etc., is avoided. The wall-plates for basement-floors are best supported on short piers carried up from the footings. Joists in single floors should never be less than two inches, nor even as small as that where it can be avoided; and they should not be farther apart than twelve inches from centre to centre. They may be strengthened by increasing their depth (which should not be less than nine inches), and may be prevented from twisting by putting a herring-bone truss between them (Fig. 133). This consists of pieces of batten an inch and a half thick and three inches wide, or thereabouts, placed diagonally between the joists, to which they are nailed in the diagonal form shown. They should be ranged in a right line, so that none of their strength may be lost, and these ranges should be repeated at intervals not exceeding five or six feet. This strutting should be done to single flooring under any circumstances, as it adds materially to its firmness, and indeed to its strength, by making the joists transmit any stress or pressure from one to another.

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* Ceiling-joists are timbers of small scantling notched on to the lower edges of the joists, and to these the laths are attached.

The strength of single flooring is materially affected by the necessity which constantly occurs in practice of "trimming" around fire-places and vacuities. Trimming is the mode of supporting the end of a joist by tenoning it into a piece of timber running at right angles to it, instead of running it on into the wall which supports the ends of the other joists; and by this means the placing of timber under hearth-stones is avoided.

Fig. 134 shows the sectional elevation of this arrangement. The cross-piece A, called the *trimming-joist*, is united at both ends to the joists running the entire length or breadth of the floor by means of strong tenons; and these joists, having to bear the weight of several which run into the trimming-joist, should be made stouter than the others; and a brick arch, B, called the *trimming-arch*, should be thrown across from the wall to the trimming-joist, on which the hearth-stone C may rest.

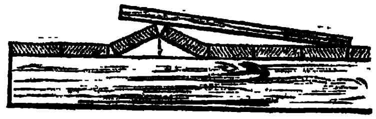


Fig. 140.

Fig. 137.

Fig. 138.

Fig. 139.

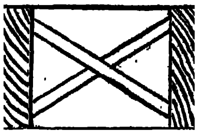


Fig. 133.

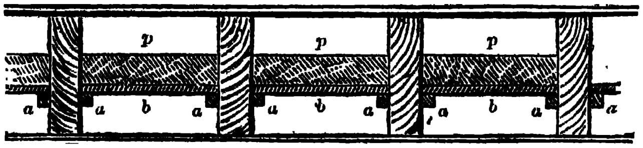


Fig. 135.

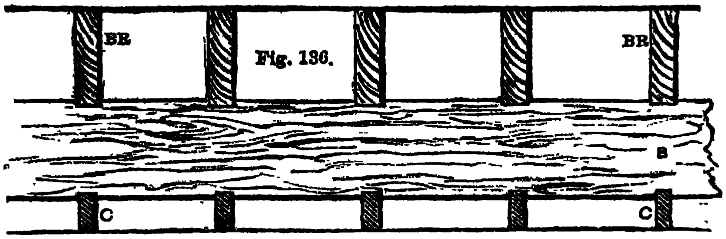


Fig. 136.

Fig. 135 shows the mode of preventing sound passing through floors. Narrow fillets, *a a*, are nailed to the floor-joists, and on these boards called sound-boards, *b b b*, are fixed; "pugging," which is a coarse sort of mortar, etc., is then filled in as at *p*.

Double Flooring, a section of which is shown in Fig. 136, consists of three distinct series of timbers—viz., the binding, B, bridging (or floor), BR, and ceiling-joists, C. In this system the binders are the real supports of the floor; they run from wall to wall, and carry the bridging-joists above, and the ceiling-joists, C, below. Binders need not be less and should not be more than six feet apart. The bridging-joists are notched down on to the binders in the manner shown in Fig. 112; but in notching the ceiling-joists to the lower edge of the binder the whole notch must be taken out of the ceiling-joist, as the lower part of the binder must not in any way be wounded or weakened. The details, as already given in relation to single floors are, of course, equally applicable to the system here described.

Framed-Flooring, a section of which has already been shown (Fig. 117), is composed of girders (G), bridging joists (B), floor-joists, and ceiling-joists.

Girders are large beams, either formed of one piece or built up, according to the length required and the size and strength of which timber can be procured. They are intended for longer bearings than binders, and may be strengthened by trussing, as already shown in Figs. 100, 101, 103, and 104. To be efficient, the height of the truss should always be greater than the girder itself, and the strength is increased by extending that height as the space or bearing increases.

Binders are made dependent upon the girders by means of double tusk tenons. This mode of joining has already been illustrated in Fig. 117.

It must be observed that the binders should not be mortised into the girders opposite to each other, since the girder would be unduly weakened by being mortised on both sides at the same place.

The floor-boards are nailed either at one or both edges. The longitudinal joints, or those in the direction of the fibres, are either square (Fig. 137), ploughed and tongued (Fig. 138), or rebated and lapped over each other (Fig. 139).

Ploughed and tongued and rebated joints may be used where the apartment is required to be air-tight, the heading joints being either square or ploughed and tongued. Sometimes, instead of a tongue extending all the length, separate pins are used, called dowels, which run into holes in the next board. In square longitudinal-jointed floors it is necessary to nail the boards on both edges; but where the boards are dowelled, ploughed and tongued, or rebated, one edge only need be nailed, as the tongue or lapping is sufficient to keep the other down.

In the most common kinds of flooring the boards are folded together in the following manner:—Supposing one board already laid and fastened, a fourth, fifth, sixth, or other board is also laid and fastened, at such a distance as to admit of two, three, four, five, or more boards between the two, but which can only be inserted by force, as the breadth of the opening must be barely that of the aggregate width of the boards, in order that the joints may be close when they are all brought down to their places. For this purpose, a plank (Fig. 140) may be thrown across the separate boards laid, which may be forced down by two or more men jumping upon it. This done, all the intermediate boards may be nailed down, and the operation is to be repeated until the whole is complete. In this system, which is called "folded flooring," less than four boards are seldom laid together. No attention is paid to the heading joints, and sometimes three or four such meet in one continued line.

In dowelled floors, the distances to which the dowels (or projecting pins) are set are from six to eight inches, generally one over each joist and one over each interspace. No heading joint of two boards ought to be so disposed as to meet the heading joints of two other boards, and thereby form a straight line equal to the breadth of two boards.

Laying down the floor-boards is usually classed under joinery, but it is found more convenient to treat of this branch in the present section, in connection with the construction of the floors themselves.

AGRICULTURAL CHEMISTRY.—VII.

BY CHARLES A. CAMERON, PH.D., M.D.,

Professor of Hygiene in the Royal College of Surgeons, Ireland, etc.

CHAP. VII.—ON MANURING AND NATURAL MANURES.

As stated in a previous chapter, it is practically impossible to reduce, by any system of tillage, fertile land into a state of barrenness. The food of plants is so abundant in soil and air, that it is beyond the power of man to diminish its amount, except to a trifling extent. In order, however, to maintain the soil in its highest degree of productiveness, the elements extracted from it in the form of crops must be in great part restored in the form of manure. A naturally good soil, carefully tilled but unmanured, will yield average fair crops for many years; but good land, which is both properly tilled and abundantly supplied with manure, alone yields maximum returns for the labour and materials expended upon it.

The laborious and long-continued experiments of Messrs. Lawes and Gilbert have given results which prove that in wheat land of average quality the application of tricalcic or monocalcic phosphate (bone phosphate and soluble phosphate of lime) frequently produces little, if any, effect upon the growth of wheat. That plant possesses an extensive root-absorbing surface, and throws out its rootlets to a considerable distance from its stem. It also, when sown in autumn, is enabled to collect mineral matter from the soil during the winter and early spring. On the other hand, barley, which is sown in the spring, has less time to draw upon the resources of the soil, and therefore it is far more likely to be benefited by the direct application of manures containing phosphates. Both wheat and barley, and the cereals generally, appear to be much more influenced in their growth by the application of ammoniacal manures, than by that of phosphatic or alkaline compounds. Potassic silicate, believed at one time to be an excellent application to the cereals, on account of the large amount of silica or flint they contain, has been proved to have no effect whatever in strengthening the stems of those plants. The cereals, if well supplied with nitrogenous fertilisers, may be grown more frequently in the rotation than is usually the case; indeed, they may be produced year after year without the interposition of other crops, but for the difficulty of keeping the fields free from weeds.

Most leguminous plants—vetches, clovers, etc.—do not seem to be much benefited, as a general rule, by the application of ammoniacal manures. Potassium salts are, on the other hand, almost certain to stimulate the growth of these crops. The large leaf-surface of all the members of the Leguminosæ enables them to extract abundance of combined nitrogen from the atmosphere, and hence the amount of ammonia in the soil often increases, instead of decreasing, during the growth of clovers and allied plants. In the rotation wheat should always succeed clover, because the latter crop will provide the former with nitrogenous matter, which is so indispensable to the luxuriant development of the cereals.

Bulky organic manures (farm-yard manures, decomposing straw, and similar matters), and the manufactured fertiliser known under the term superphosphate of lime, produce marked effects upon root-crops—turnips, mangolds, etc. The natural grasses grow luxuriantly if supplied with nitrogenous manures, and they are not to any important extent dependent upon the use of bulky natural manures. Sodic nitrate generally produces a powerful stimulative action upon the grasses. Potatoes appear to be far more benefited by the application of potassium salts (kainit, "muriate of potash," and kelp) than by that of ammoniacal salts. In many cases the nitrogen of sodic nitrate (nitrate of soda) is more effective when applied to potatoes than the nitrogen of ammonia.

The manures used in this country are very numerous, and are derived from the three kingdoms of Nature. We cannot refer to all that are in use, for our space will only permit us to describe the more important ones.

Farm-yard manure is the staple fertiliser of the British farmer, and in general all others are more or less supplemental. It is composed of the liquid and solid excreta of various animals commingled with straw; but it occasionally includes ashes, turf, mould, leaves, and all kinds of house rubbish of an organic origin. Its composition varies very much, and depends to a great extent upon the care with which it is preserved. Some years ago we made four analyses of farm-yard manures, and the following were the results at which we arrived:—

	No. 1.	No. 2.	No. 3.	Nc. 4.
Water	73·22	64·12	65·22	69·14
Organic matter	21·17	29·28	28·14	24·21
Containing ammonia free, in combination with acids, and latent	(0·150)	(0·784)	(0·550)	(0·612)
Tricalcic phosphate	1·73	1·75	1·88	1·64
Alkaline salts	1·30	1·00	1·86	0·94
Calcium and magnesian compounds	1·38	1·82	1·24	2·12
Silica, oxide of iron, etc.	1·20	1·94	1·66	1·95
	100·00	100·00	100·00	100·00

No. 1 was composed chiefly of the solid excretion of the horse and cow, the liquid excreta having been allowed to drain away, and most of the soluble portion of the manure having been washed out by rain. Nos. 2 and 3 were composed of the solid and liquid excrement of horses and cows, and as they had been properly preserved, the amount of ammonia was high. No. 4 contained some pig manure in addition to that derived from horses and oxen. It was carefully preserved under cover, and its proportion of ammonia was also large.

The composition of the excreta of the farm animals is shown in the following tables:—

COMPOSITION OF THE SOLID EXCRETA OF THE ANIMALS OF THE FARM.

1,000 parts contain—	Horse.	Cow.	Sheep.	Pig.
Water	750	850	640	700
Solid matters	220	150	360	220
Containing nitrogen equal to ammonia	6	3·5	6	7
„ phosphoric acid equal to phosphate of lime	8	6	5	5
Alkaline salts	3·5	2·20	3	5·5

COMPOSITION (PER 1,000 PARTS) LIQUID EXCRETA OF THE FARM ANIMALS.

	Horse.	Cow.	Sheep.	Pig.
Water	900	920	900	975
Solid matter	100	80	100	25
Containing nitrogen equal to ammonia	14	9	14	3
„ alkaline salts	14	16	10	2

The amount of phosphoric acid is very small in the liquid excrements, varying from a trace to about 0·1 per cent. in the case of horses, oxen, and sheep. In pigs' liquid excreta it amounts to from 0·75 to 1·5 per 1,000 parts.

The composition of the excreta of the farm animals is very variable, and is greatly influenced by the nature of the animal's food, and other conditions. Two specimens of the liquid excretion of the sheep which I analysed (see *Gardeners' Chronicle* for March, 1860) gave the following very different results:—

	No. 1.	No. 2.
Specific gravity	1045	1014
Water	87·16	95·88
Urea and undetermined organic matter	9·38	2·95
Yielding by combustion with soda—lime, ammonia	(3·20)	(0·85)
Inorganic matters, chiefly alkaline salts	3·46	1·17
	100·00	100·00

No. 1 had been obtained from a sheep "highly fed," and No. 2 from a sheep poorly fed.

The solid manure of the horse is very valuable. It decomposes rapidly in the soil, which becomes thereby sensibly warm. It is, therefore, properly termed by farmers a *hot manure*. On the other hand, cow manure is cold, because it long resists decomposition. Owing to the coherent, pasty character of this manure, it is difficult to distribute it equably throughout the soil. Sheep manure is nearly as valuable as that furnished by the horse, but it does not decompose so readily. The manure of the pig appears to vary more in composition, probably owing to the omnivorous nature of the porcine species, than that of the other three animals above referred to. It is a *cold* manure, and is pasty and tenacious. Its composition indicates that it is capable of greatly enriching the soil, and on the Continent it is held in great repute amongst the farmers. For my part, I should prefer horse manure to it.

The best position for the manure heap is on level ground, for if placed on a sloping site the drainage from it soon diminishes its value, and if it be deposited in a hollow its base soon becomes rain-water. A paved site is desirable, as soft soil absorbs valuable soluble matters from the manure. The larger the heap is the less it loses by the influence of sun, air, and rain. The common practice of allowing the manure to remain in small heaps is most wasteful. When the heap is large and compact, very little loss is sustained by evaporation; but heavy rains dissolve and carry away some of the soluble matters. This loss may be averted by surrounding the base of the manure heap with earth or peat mould, and when the latter becomes saturated with the fertilising matters it may be thrown up on the top of the heap. A stratum of fine earth or peat-mould a foot in depth constitutes an excellent foundation for the manure heap. Farm-yard manure may be spread over the field a long time before it is actually required. Under such circumstances, it loses little, if any, of its fertilising ingredients, as the soil absorbs and retains them.

The treatment of liquid manure is a point of considerable importance; but we shall postpone its consideration until we come to treat upon the subject of liquid sewage.

WEAPONS OF WAR.—VIII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

GREAT GUNS AND THEIR PROJECTILES (*continued*).

In our last paper we treated of smooth-bore ordnance, and of the various natures of shot which are used with the same—solid, steel, chilled, hollow, case, and grape shot.

We pass now to the consideration of the second group of projectiles, Shells. There are two great classes of shell—Common shell and Shrapnel shell. The common shell, for smooth-bore guns, is a hollow sphere of cast-iron filled with powder and fitted with a fuse, which is so arranged as to explode the shell either at a particular time after it has left the gun, or when it strikes against some hard object. A shell is, in fact, a small mine which is transferred by the power of a gun to any spot where its effect may be required to be produced: it has been called a "flying mine," and the effect, it will be observed, is really independent of the gun. That is to say, a common shell, if deposited on a particular spot by hand and then fired, would cause almost as much destruction as if it had been shot on to that spot from a gun. This, at least, is the primary application of a common shell, and it is one which it is important to appreciate, because it constitutes the leading distinction between shells of the common and shells of the Shrapnel class. It follows from the above, that a common shell acting as a mine is especially destructive against the *matériel* of an enemy. It destroys his parapets; it blows down his walls and defences; it carries destruction into his towns and villages; but, beyond and above all, it is especially terrible when it can be introduced into his ships. Shells are more dreaded by the sailor than any other projectile, and naturally so; for the bursting of a shell in the confined space between the decks of a vessel is destructive alike to men and material; it blows the former to pieces, it destroys and sets fire to the latter, and it causes confusion and terror by its noise and smoke. The following passage, which gives a "realised epitome" of shell effects on board ship, has been often quoted, but may be here fitly reproduced. It is an account of the fight between the iron-clad *Merrimac* and the wooden ship *Congress*:—"The first shell that burst within the *Congress* killed every man at the nearest gun; another and another burst among the crew, and the ship was soon a slaughter-house. Operations were now out of question. The wounded were in crowds horribly cut up. The ship, too, was on fire; the shells had kindled her woodwork in various places. Nearly all the guns were dismounted, the bulkheads blown to pieces, handspikes and rammers shivered, and the powder-boys all killed. Everything was in fragments, black or red, burnt or bloody. This horrible scene lasted about an hour and a half, and then she struck." This vivid description was given by an eye-witness.

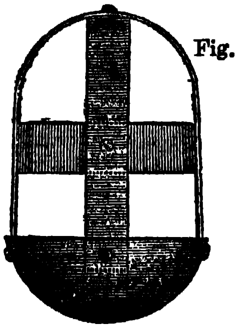


Fig. 3.

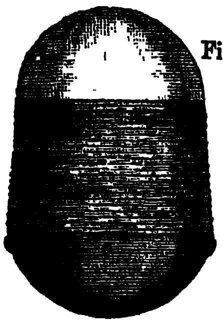


Fig. 4.

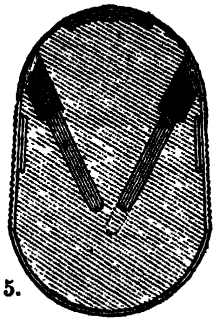


Fig. 5.

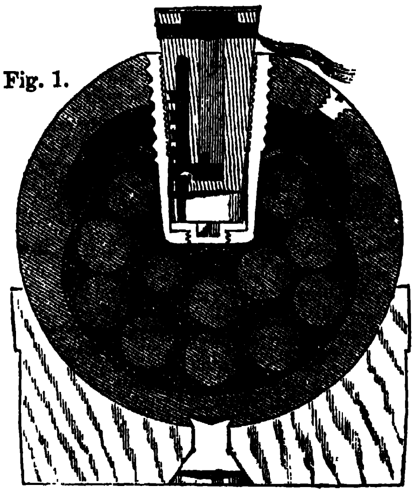


Fig. 1.

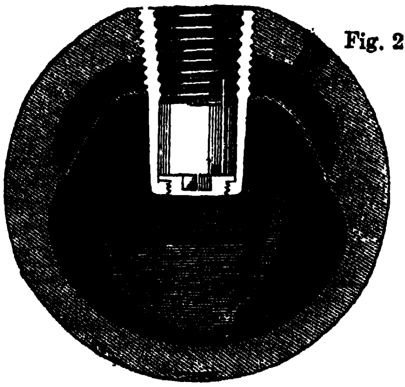


Fig. 2.

Fig. 1.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITH FUSE COMPLETE. Fig. 2.—SECTION OF DIAPHRAGM SHRAPNEL SHELL, WITHOUT BULLETS. Fig. 3.—SKELETON FRAME OF GROUND LIGHT BALL. Fig. 4.—GROUND LIGHT BALL COMPLETE. Fig. 5.—SECTION OF GROUND LIGHT BALL.

A secondary use of the common shell is to act much as the Shrapnel acts—viz., to burst somewhat in advance of the object fired at, when the fragments, continuing their flight, spread out and act in the same way as a charge of case or grape. But this is to be understood as distinctly a secondary use of common shells; for in this case the large bursting charge which the shell contains is in a great measure thrown away. Indeed, it may be said to detract from the efficiency of the projectile, because it blows a number of the fragments sideways, and arrests the progress of others.

But this brings us to that class of shell which is specially intended to act in this way—Shrapnel shell. The first idea of these important projectiles was conceived by General Shrapnel, of the Royal Artillery, at the siege of Gibraltar, in 1781. The guns were firing at a range beyond that of case or grape, and some effective *direct* fire was made with common shell fired from 24-four pounders with large charges of powder. The projectile's velocity was very great, and the loss to the enemy was considerable. It then occurred to General Shrapnel that if he were to fill these shells with musket and carbine balls, reducing the bursting charge to a *minimum*, consistent with the opening of the shell, and increasing the firing charge to a *maximum*, he would be able to produce a still more destructive fire. In this change we note the distinctive difference, which cannot be too clearly appreciated, between common and Shrapnel shell—viz., the difference, that while the former depends upon the explosive effect of its own charge, the latter depends upon or derives its effect from the charge of the gun. A high velocity is not necessary in the first case; it is essential in the second. A large bursting charge is essential in the first case; it is not only not essential, but absolutely prejudicial in the second. The original Shrapnel shell, as designed by General Shrapnel, was, in fact, a thin common shell filled with bullets instead of powder, and having only so much powder in among the balls as would suffice to open the shell. The object of making the shell as thin as possible was, first, that it might contain as many balls as possible; secondly, that a very small bursting charge might open it. These projectiles were first introduced about the year 1803, and were used at the battle of Vimiera in 1808, and at other actions during the Peninsular war, with an effect to which the French, against whom they were fired, bear ample though unwilling testimony.

The action of the shell is as follows:—It leaves the gun like any other spherical projectile, travelling to the point at which the time-fuse has been set to explode it—which should be a short distance in front of the object aimed at. When it arrives at this point, if the action of the fuse be satisfactory, the shell will be opened, and the bullets and fragments will "continue their forward course with a communicated velocity equal to that of the shell at the moment of fracture, and describing, as they slightly disperse, 'a curved cone, the apex of which is at the point of explosion.'" The Shrapnel shell thus acts as case or grape at distances beyond those at which case and grape can be effectively employed. The Shrapnel shell has practically the effect of carrying forward the muzzle of the gun to within such a distance of the enemy as will enable a case-fire to be delivered. Actually the muzzle of the gun is, of course, not advanced; but practically this is what happens, for the breaking up of the projectile, which with case occurs at the muzzle, is postponed until the projectile arrives within a short distance of the enemy. Indeed, when Shrapnel shell were first introduced, they were called by a name which exactly describes them—"spherical case shot." The present name was not adopted until many years afterwards, as a compliment to the inventor. Since the first introduction of Shrapnel shell, some important improvements and modifications have been adopted. It was found that the shells sometimes were broken up by the shock of discharge, due to the friction of the powder between the balls. To obviate this it was necessary to separate the powder from the balls, and this was done by introducing into the existing store of Shrapnel a tin cylinder, which occupied the centre of the shell, and contained the bursting charge. These shells were known as "improved Shrapnel," and they have only recently disappeared from the service. When new shells had to be made, General (then Captain) Boxer, R.A., proposed a different arrangement. He proposed to separate the bursting charge from the bullets by enclosing it in a small chamber formed on one side of the shell, by the insertion of a wrought-iron plate or "diaphragm." The accompanying drawings (Figs. 1 and 2) show the construction of the "diaphragm Shrapnel shell."

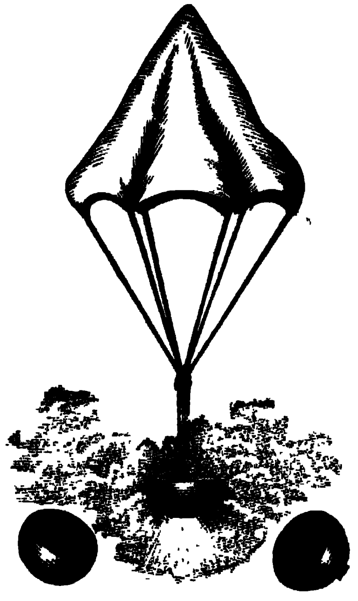


Fig. 6.—PARACHUTE IN ACTION.

The advantage of placing the bursting charge at one side, instead of in the centre, was that it avoided the excessive dispersion of the balls at the moment of rupture. But in order to ensure the proper opening of the shell, it was necessary to provide it with internal grooves, or "lines of least resistance," down which the powder would act. The powder is introduced into the chamber through a small loading-hole, and the fuse communicates with the powder in this chamber through a small fire-hole in the brass socket. To prevent the bullets from conglomerating under the shock of discharge, they are made of hardened lead, and have coal-dust shaken in between them. Such is the diaphragm Shrapnel shell for smooth-bore guns. We shall see hereafter how General Boxer has successfully applied the principles of this construction to the Shrapnel shell for rifled ordnance.

It will be observed that the shell in our drawing is fitted with a wood bottom, riveted on. All shells are fitted with one of these bottoms, or "sabots." They serve the double purpose of presenting the right side of the shell—*i.e.*, the side away from the fuse—to the charge, and slightly diminishing "windage" (the space between the shell and bore), and thus reducing the escape of gas and the tendency of the projectiles to *ricochet* along the bore. With bronze guns, it was necessary to provide the shot, as well as the shell, with these bottoms, because otherwise a bounding movement of the shot became established, to the speedy destruction of the gun, and to the almost immediate destruction of all accuracy of fire. The method of attachment adopted for these bottoms—an expanding copper rivet—is simple and ingenious, and a great improvement on the plan formerly adopted—namely, "strapping" on the bottom with tin "straps."

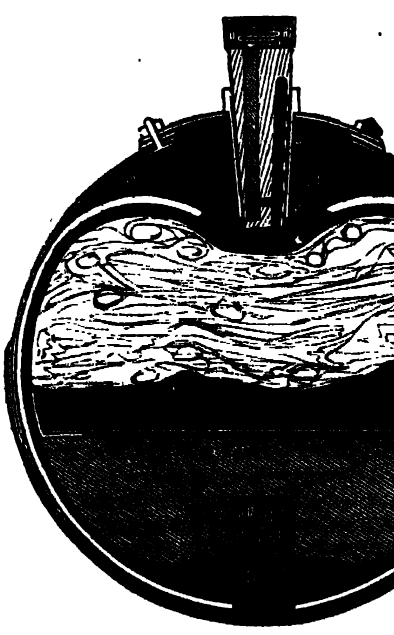


Fig. 7.—SECTION OF PARACHUTE LIGHT BALL, WITH FUSE.

We have now treated of shot and shell. There remains a third class of projectiles to speak of—*incendiary projectiles.* Of these there are six—viz., red-hot shot, Martin's shell, ground light balls, parachute light balls, and smoke balls.

Red-hot shot are merely ordinary cast-iron shot heated to a "wafer" red heat and fired, with reduced charges, against wooden shipping or any combustible material. It is necessary to fire them with reduced charges, because the expansion of the shot, by reducing the windage, increases the strain upon the gun, and because red-hot shot are required to lodge in the object fired at, and not to pass through it. These projectiles were used with great effect, and on a large scale, at the siege of Gibraltar.

Martin's shells have, in a great measure, replaced red-hot shot; although both descriptions of projectiles have lost their original value, in consequence of the substitution of armour-plated for wooden vessels. Martin's shell, so called after its inventor, a civilian, consists of a thin spherical cast-iron shell, with an interior lining of loam; shortly before use the shell is filled with molten iron. In order to ensure the breaking-up of the shell on striking an object, the sides are made thinner than the top and bottom. The loam lining, being a good non-conductor, serves the double purpose of keeping the iron in the interior hot and the external shell cool for a longer time than would be possible if there were no such lining. The shell is intended to be fired against an inflammable object—such as a wooden ship. The shock of concussion breaks the shell, and the molten contents are scattered about, setting fire to everything combustible upon which they may fall. These shells were considered by the committee which introduced them to possess greater incendiary power than red-hot shot. On the other hand, there is a certain amount of trouble and inconvenience involved in the preparation of the liquid iron. But when these difficulties are surmounted, and when the shell are used under favourable circumstances, they have been proved to be very formidable instruments of destruction.

Carcasses are thick iron shells, filled with a combustible composition, and having three holes for this composition to burn out of. The composition consists of a mixture of saltpetre, sulphur, rosin, sulphide of antimony, turpentine, and tallow. It burns with great violence for from three to twelve minutes, according to the size of the carcass, which varies from the 12-pounder to the 13-inch. Carcasses are thrown into an enemy's works, to set fire to his houses, stores, etc. etc. The composition becomes ignited at each vent by the flash of discharge, and continues burning after the carcass has fallen until it is expended. So violently does the composition burn, that it is almost impossible to extinguish it. It will even burn under water. The best mode of dealing with a carcass is to endeavour to roll it away from all inflammable material, and to smother it with earth.

The ground light ball (Figs. 3, 4, 5) is another projectile of this class. It is, however, useful rather for illuminating than for incendiary purposes. It consists of an oblong skeleton iron frame, covered with stout canvas and filled with an inflammable composition, consisting of saltpetre, sulphur, rosin, and linseed oil. The projectile has four or five vents, according to its size, from which the composition burns, for from nine to sixteen minutes, according to the size. These ground light balls are thrown from mortars at night into an enemy's work, to discover his working parties; and they are also serviceable, in the absence of carcasses, as incendiary projectiles. They are, however, open to some serious objections. In the first place, an oblong projectile is not suitable for firing out of a smooth-bore gun; neither range nor accuracy can be obtained with it. Again, if they fall short of the object, their smoke makes a sort of screen. If they fall into a ditch or on to muddy ground they are smothered; and if they do fall in the right place, they can be very easily covered over with earth, and so rendered useless as lights. Even when not extinguished, the composition is of so dull a nature that its illuminating power is very small, while the area illuminated by a projectile on the ground is necessarily restricted, even under the most favourable circumstances.

A good many of the foregoing objections, if not all, were met by General Boxer in his ingenious Parachute Light Ball. It consists of a thin wrought-iron shell, containing two half-shells of wrought iron (Fig. 7), the lower of which contains a brilliantly burning composition of saltpetre, sulphur, and red orpiment, and the upper a calico parachute, the lower part of which is attached by chains to the composition hemisphere. The shell, fitted with a fuse, is fired from a mortar. The fuse is timed to explode a small bursting charge when the shell attains its maximum elevation over the area or object required to be illuminated. On the explosion of the bursting charge, the outer shell is opened, and the two inner hemispheres begin falling. The lower hemisphere, which contains the composition, being the heavier, falls more rapidly than the other, which has, indeed, received a momentary impulse by the action of the bursting charge in the opposite direction. This jerk, and the more rapid falling of the composition hemisphere, causes the calico parachute to be pulled out and expanded (Fig. 6), and it then floats the composition hemisphere slowly down over the object to be illuminated, the composition burning brightly out of a hole at the bottom of the hemisphere, for from one to three minutes, according to size. In addition to overcoming all the difficulties and objections enumerated above as belonging to the ground light ball, the parachute light ball possesses the advantages of being serviceable at sea, or to illuminate an enemy's fleet, which the ground light ball necessarily cannot be. It can also be fired from a very light and handy mortar. This construction of projectile has been very effectively employed for firework purposes.

The Smoke Ball hardly needs any mention. It is merely a paper shell filled with a composition of gunpowder, saltpetre, coal, pitch, and tallow, which when ignited emits a dense and suffocating smoke, which is stated to be useful in expelling an enemy from mines, and in concealing one's own operations. These projectiles have also served a peaceful use in the Arctic regions, where they were employed for signalling purposes—the long column of black smoke standing out prominently against the white background of these snow-clad regions.

This completes the list of projectiles for smooth-bore guns, if we except the Manby shot, for saving lives from shipwreck, and which is not to be considered a weapon of war. We will now pass forward to another section of our subject.

SEATS OF INDUSTRY.—VIII.

BY WILLIAM WATT WEBSTER.

GLASGOW.—II.

WITH the establishment of the Union, which at the time was believed by the people of Scotland to be a great national catastrophe, a great impetus was given to the trade of Glasgow; and this event also marks an important era in the manufacturing history of the city. Up to this period the foreign trade of Glasgow had been almost altogether restricted to the continent of Europe; it was now extended to the colonies. When this trade was first entered upon, the Glasgow merchants had no suitable ships of their own, and were therefore obliged to charter vessels belonging to other ports. The nature and "canny" system of the trade engaged in may be gathered from the following description taken from Gibson's "History of Glasgow:"—"A supercargo went out with every vessel, who bartered his goods for tobacco, until such time as he had either sold all his goods, or procured as much tobacco as was sufficient to load his vessel. He then returned immediately, and if any of his goods remained unsold he brought them home with him." In a very short time Glasgow became the principal centre of the tobacco trade in Great Britain, and the Virginia merchants, or "tobacco lords," as they were called, became notorious for their wealth and pride. A curious story is told of the first venture made by Glasgow merchants in the tobacco trade. In order to keep down expense, the captain of the ship sent out was appointed to act as supercargo. "This person," says the old merchant who has recorded the event, "although a shrewd man, knew nothing of accounts; and, when, on his return, he was asked by his employers for a statement of how the adventure had turned out, told them he could give them none, but there were its proceeds; and threw down upon the table a large hoggar—that is, a stocking—stuffed to the top with coin. The venture had been a profitable one; and his employers conceived that if an uneducated, untrained person had been so successful, their gains would have been still greater had a person versed in accounts been sent with it. Under this impression, they immediately dispatched a second adventure with a supercargo, highly recommended for a knowledge of accounts, who produced to them a beautifully-made-out statement of his transactions, but no hoggar." It is estimated that more than one-half of the disposable capital of the city was embarked in the tobacco trade, from about 1735 till the declaration of American Independence in 1776. A notion of the extent of this trade in its best days may be formed from the statistics for the year 1772, which show that out of 90,000 hhds. of tobacco imported into Great Britain, Glasgow alone imported 49,000 hhds. The year preceding the American War of Independence—which closed for ever the tobacco monopoly which Glasgow up to that time had enjoyed—was still more remarkable, for there were imported into the Clyde in that year no less than 57,143 hhds. of tobacco, which were the property of forty-two merchants. When the tobacco trade collapsed, the Virginia merchants turned their attention to the West Indies, and soon transformed themselves into "West India lords." Sugar cultivation in the West Indies and the introduction of cotton manufactures had opened out new paths to opulence.

It was at this period that the cotton trade of Glasgow commenced. Very shortly after the cultivation of cotton was introduced into the Southern States of the American Union, agents of Glasgow houses were established at Charlestown and New Orleans, in order to facilitate the interchange of American cotton and British manufactures. This trade was prosecuted with extraordinary vigour, and "cotton lords" soon came to take the place of the "tobacco lords" of a bygone day. It was also at this date that cotton manufacture was begun in Scotland, the first cotton-mill being built at Rothesay in 1778, by an English company; but before many years passed it was bought by Mr. David Dale, a Glasgow merchant, who became one of the most extensive cotton manufacturers in the country. The second cotton-mill built in Scotland was at Dovecot Hall, on the banks of the Leven, in Renfrewshire, and it soon proved so remunerative that it was enlarged, and five other mills were built in the vicinity. Among the earliest factories in Lanarkshire may be mentioned the celebrated New Lanark Mills, erected by Mr. David Dale, in 1785, in which Sir R. Arkwright had a share. Spinning operations were commenced in this mill in 1786, and two years later another mill was built, which was destroyed by fire before it had been completed, but was rebuilt in the following year. Subsequently two other mills were erected in the neighbourhood. From the first, Glasgow was the centre of cotton manufacturing enterprise in Scotland; and nearly the whole of the cotton goods that have been made in that country have been manufactured either by or for firms belonging to that city. Within fifty years of the time when the first cotton factory was erected in Scotland, Glasgow was the centre of about 100 cotton-mills, and before the lapse of another decade the number of cotton-mills in Scotland had nearly doubled. The increase in the imports of cotton into Glasgow during this period was, as a matter of course, proportioned to the increase in the number of mills. Thus the quantity of cotton imported into the Clyde in the year 1775 was 508 bales, or 137,160 lb.; in 1790 it was 6,500 bales, or 1,757,504 lb.; in 1812, 43,000 bales; in 1824, 54,708; and in 1834 the quantity had risen to 95,763 bales. The latter figures represent a fifth of the cotton imported into Britain in 1834; and it is estimated that at least three-fourths of the whole quantity imported into the Clyde, or 71,777 bales, were worked up by Glasgow manufacturers.

But before the introduction of cotton, the manufacturers of Glasgow and Paisley had acquired a high reputation for the excellence of the linen fabrics they produced. Linens, lawns, and cambrics were, indeed, the staple manufacture of Glasgow till after the close of the American War. The first tape-factory in Britain was established at Glasgow by Mr. Alexander Harvey, in 1732. This enterprising citizen abducted two inkle-looms, and an experienced workman from Haarlem, at the risk of his life; and it was the Dutchman he brought over to this country who first initiated the manufacturers of Manchester into the mysteries of tape-making. As might have been expected, the cotton cloths manufactured at Glasgow when the fibre began to be used, and for some time afterwards, were of the coarsest description. A handkerchief formed of linen warp and cotton weft, which went by the name of a "blunk," was the chief article produced. It was not very long, however, before the Glasgow manufacturers attempted and succeeded in turning out a finer quality of cloth. About the year 1784, Mr. James Monteith manufactured a web of muslin from some "bird-nest" Indian yarn, and presented a dress made out of this fabric to Queen Charlotte. It was at this time that the cotton-spinning machinery of Hargreave and Arkwright was introduced into England, and as this machinery produced thread sufficiently fine for muslins, and as muslins were a profitable branch of manufacture, the Glasgow manufacturers lost no time in adopting it. In a very few years Glasgow had a large trade in plain and printed muslins, and Paisley became celebrated for fancy muslins. These goods soon came into competition with the productions of the Indian looms, for as early as the year 1793 it is stated in a report of the East India Company, on the subject of cotton manufacture in this country, that "every shop offers British muslins for sale equal in appearance and of more elegant patterns than those of India, for one-fourth, or, perhaps, more than one-third less in price." Under the date 1785, the following passage occurs in "Macpherson's Annals of Commerce:"—"The manufacture of calicoes, which was begun in Lancashire in 1772, was now pretty generally established in several parts of England and Scotland. The manufacture of muslin was begun in England in 1781, and was rapidly increased. In the year 1783 there were above a thousand looms set up in Glasgow for the production of the most beneficial article, in which the skill and labour of the mechanic raised the raw material to twenty times the value it was when imported." The spinning of cashmere yarn has been carried on at Glasgow since 1831, and merino yarn has been produced there since 1833.

It is well known that it was at Glasgow that James Watt made his first model of the steam-engine, and it was at Port-Glasgow that the *Comet* was built, the vessel that first demonstrated to Europe the practicability of steam navigation. The first steam-engine applied to the spinning of cotton in Glasgow was erected at Springfield, on the south side of the Clyde, in 1792. In the following year two power-looms were fitted up in the city by Mr. James Louis Robertson, and for a time were driven by a Newfoundland dog walking in a drum. In 1793, 40 power-looms were at work at Milton; and by 1801 Mr. John Monteith had 200 looms in operation at Pollockshaws, near Glasgow. Steam now began to be generally applied, and the number of power-loom factories increased with astonishing rapidity. In 1850 the number of spindles employed in cotton-spinning connected with and dependent on Glasgow amounted to 1,683,093; and the cotton consumed reached a total of 45,000,000 lb., or 120,000 bales; while the power-looms numbered 23,564, producing a daily average of 625,000 yards of cloth. Four years later there were from 26,000 to 27,000 power-looms in the Glasgow district, and the product was consequently proportionately increased. A return made to Parliament in 1862 shows that there were in Glasgow and its dependencies in the previous year 163 factories, with 1,915,398 spindles, 30,110 looms, giving employment to 41,237 persons. Since that year the number of factories has decreased, but the amount of production has risen notwithstanding. In 1861 the number of yards of cotton cloth exported from the Clyde was 150,754,631; in 1867, 206,394,756 yards were exported. During the Civil War in America, the trade was, of course, in a state of stagnation, but it rapidly recovered from the blow.

The great cotton manufacturing district of which Glasgow is the centre comprises New Lanark, Paisley, the Water of Leven, Kilbrachan, Johnston, Lochwinnock, Rothesay, and Old Kilpatrick. The Stanley Mills, near Perth, and the Deanstoun Mills near Doune, are also two outlying and very extensive cotton factories belonging to Glasgow, which were planted in these remote localities on account of the plentiful supply of water-power and labour. A few years ago, Mr. J. M'Donald, of Messrs. D. and J. M'Donald and Co., the eminent firm of sewed muslin manufacturers in Glasgow, stated before a committee of the House of Commons that their house employed upwards of 20,000 persons in Ireland, and that the amount of wages paid to them exceeded £3,000 per week, or about £160,000 per annum. There are upwards of thirty-five other sewed muslin manufacturers in the city—several as extensive as the Messrs. M'Donald—and it is estimated that they give employment to about 148,000 Irishwomen, who receive £1,184,000 per annum in wages. The shirtmakers of Glasgow also employ about 30,000 Irishwomen in shirt-making.

The next most important branch of trade in Glasgow is the iron trade. Forty years ago there were only sixteen smelting furnaces in the vicinity of Glasgow, with an average out-put of 2,500 tons of pig-iron each. The manufacture of malleable iron is of recent date in Scotland, and no reliable record of the quantity produced was kept till the year 1845, when it amounted to 35,000 tons. In 1854 the quantity of malleable iron produced was 125,000 tons, and of pig-iron 750,000 tons. This trade has been greatly extended since the period to which these figures refer. The most eminent of the "iron lords" of Glasgow are the Messrs. Baird, of Gartsherrie. This firm owns 42 blast-furnaces, employing 9,000 men and boys, and producing about 300,000 tons of pig-iron per annum, or about one-fourth of all the pig-iron made in Scotland. At the Gartsherrie branch of their establishment, the Messrs. Baird employ 3,200 men and boys, and make 100,000 tons of pig-iron per annum; the daily consumption of coal being upwards of 1,000 tons. Nineteen-twentieths of the coal used at this work is taken from mines within half a mile of the furnaces. For forty years the coals used at Gartsherrie were got from a mine close to the furnaces; and the iron-stone was for many years found in the immediate neighbourhood, but has now to be brought distances varying from two to twenty miles. A complete system of railway communication has been constructed for its conveyance, and the Monkland Canal is also used for the same purpose.

The fame of the iron ship-builders and marine engine-makers of Glasgow has for many years been the boast of her citizens. These trades have of recent years expanded to extraordinary proportions, and have materially contributed to the prosperity of the city. Large numbers of ocean and river steamers are yearly launched on the Clyde, and some of the finest steamships in the world have been constructed in the neighbourhood of Glasgow. The increase in the trade of the port is as remarkable as any element in the prosperity of the city, and has been dependent on the extensive improvements which have been effected on the river. About fifty years ago the depth of the Clyde opposite Glasgow was barely five feet; now it is fully twenty, and ships of the largest size can load and unload at the quays. The length of quay-wall in the harbour is about 14,000 feet. No account of Glasgow would be complete that took no notice of the chemical works of the Messrs. Tennant, which are the largest in the world, and comprise sixteen acres of ground under roof. The principal chimney-stalk at these works is 435 feet from the ground, and 450 feet from the foundation. This gigantic column has been surpassed, however, by a "stalk" erected a few years ago in its neighbourhood, which rises to an altitude of 468 feet from the foundation, and is composed of a million and a half of bricks. The principal water supply of Glasgow is obtained from Loch Katrine (a distance of forty miles), and this undertaking cost the city upwards of £900,000.

Glasgow owes no inconsiderable portion of its importance as a trading and manufacturing centre to its position in the middle of a district rich in coal and iron, the two principal factors of modern history. According to calculations made by Dr. Strang, Glasgow and its suburbs contained 446,639 inhabitants in 1861; and it is believed that the population is now considerably over half a million.

TECHNICAL DRAWING.—XXVII.

THE PROJECTION OF SCREWS (*continued*).

FIG. 255 is the plan and Fig. 256 is the elevation of a square-threaded screw, the working of which the student will understand, the system being the same as in the last study.

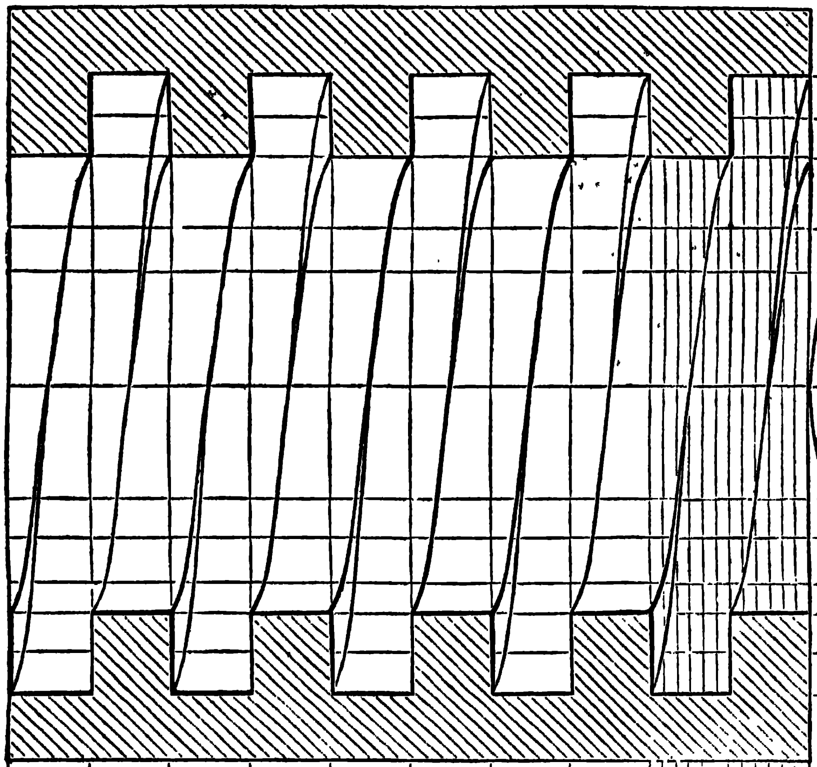


Fig. 258.

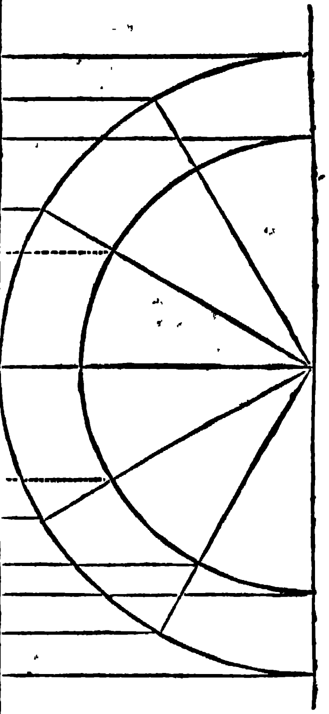


Fig. 257.

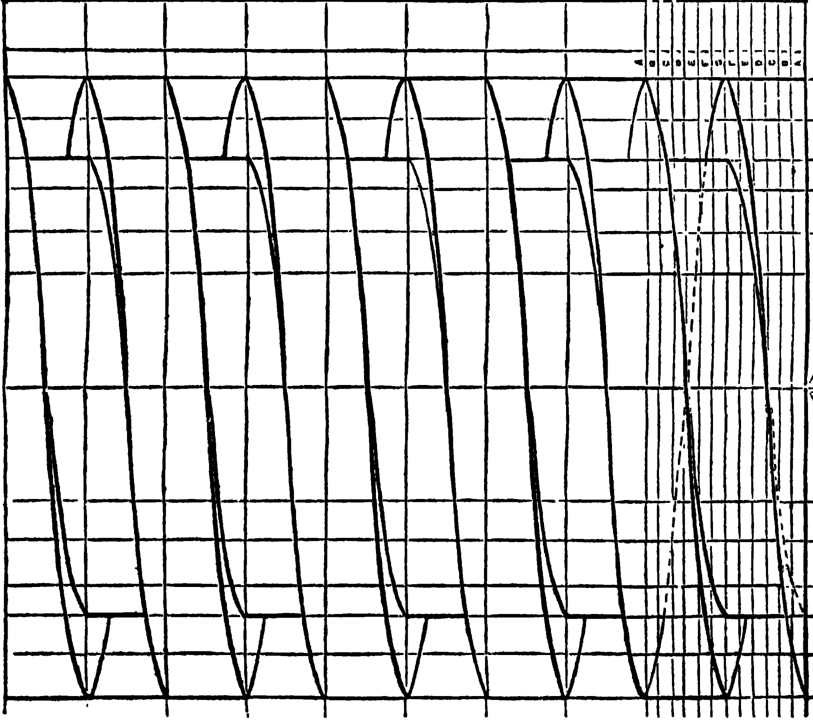


Fig. 256.

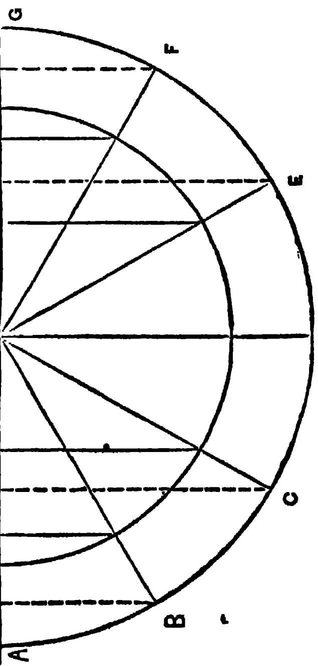


Fig. 255.

The thread and the space are equal, and the depth of the groove is the same as the width of the thread.

Having projected the first curve, which is the upper line of the thread, and having carried this helix up as far as may be required, set off the width of the thread on the perpendiculars below each of the points through which the curve has been drawn. Through the points thus obtained the lower curve of the thread may be drawn.

The points of the double helix on the inner cylinder are projected in the same manner, and therefore no further instructions will be needed.

Fig. 257 is the plan and Fig. 258 is the sectional elevation of the nut of this screw; the last is projected from the plan (Fig. 257), and the heights are carried on from the elevation of Fig. 256, the reverse curves, as before, being used. Templets for this figure may be used as in the former case.

Screws may have one, two, three, or even more threads, according to the velocity which their action may be required to produce. A double-threaded screw is one in which the pitch of any individual helix includes two threads; a three-threaded screw is one in which three threads are embraced, and so on.

Fig. 259.—This figure represents a pair of spur-wheels in

gear. The radius of the larger wheel, with 42 teeth, is 15¼", and that of the smaller, with 24, is 9".

Having drawn the pitch-circles, and having set off the pitches and divided them into teeth and spaces, as already shown, draw the circles for the points and roots of the teeth; then the faces of the teeth (which in design and practice are epicycloidal, but which in drawings are approximately rendered by arcs struck with a radius equal to the pitch), and finally the flanks which are radial, but which are turned off into the circle of roots by arcs, are to be drawn.

The smaller wheel is a mere disc with teeth; the larger one has six arms.

Draw the circle representing the rim of the wheel, about as deep as the distance from the pitch-circle to the root of the teeth. Divide this circle into six equal parts, and draw radii: these will be the centre lines for the arms. Next draw the boss, central aperture for the shaft, and the key-bed; then on each side of the six central lines set off, first, half the thickness of the central ridge or flange of the arms, and then the web, by which these are strengthened.

It will be seen that the lines of the web do not run straight into the boss, or into the part supporting the rim, but turn off in each case by arcs, as already shown.

It will be observed that when wheels are in gear there are three teeth of each engaged, one tooth of each wheel touching in the pitch-line, one pair just parting, and one coming gradually into full action.

In this example the central flange of the arms and the rim, instead of running by arcs into each other, are both bevelled so as to accomplish the same end—viz., easy delivery in moulding

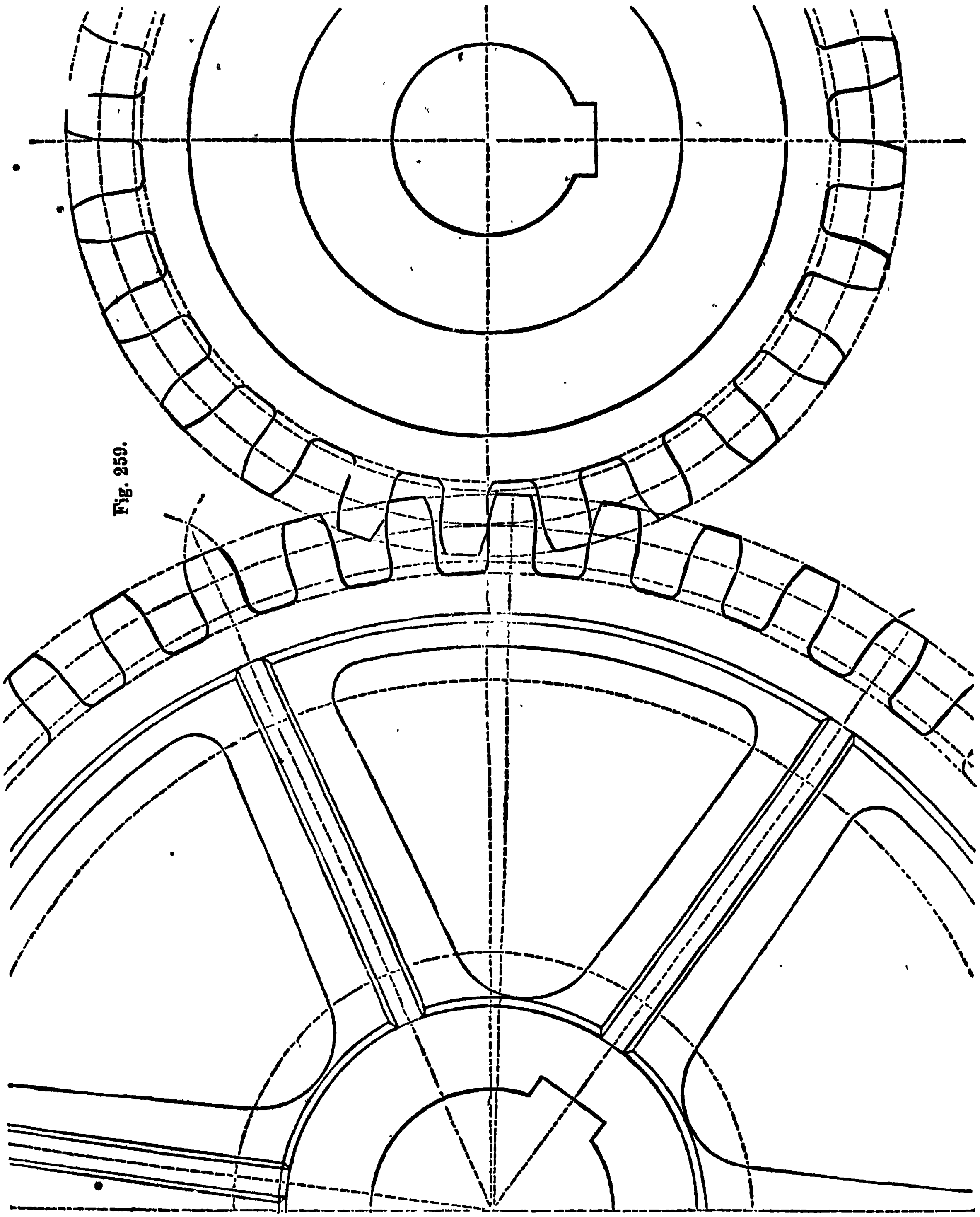


Fig. 259.

VEGETABLE COMMERCIAL PRODUCTS.

XV.

DYE PLANTS (*continued.*)

Orchella Weeds (*Roccella tinctoria*, *R. fuciformis*, and *R. hypomecha*, L.; natural order, *Lichenes*).—These lichens, which constitute the orchils of commerce, are of an ash-grey colour, having a thallus much branched, flattened, and mealy in appearance, from one inch and a half to two inches in length. The blue dye known under the name of archil or orchil is prepared from these plants, which grow on all the rocky coasts and islands of the Mediterranean, and also in the Canary Islands, Madagascar, Cape of Good Hope, and South America. The colour yielded is not in itself a fast one, but it so greatly improves others that orchil is regarded as indispensable by the dyers. The imports into this country are about 600 tons per annum.

The Tartar Lichen (*Lecanora tartarea*, L.), indigenous to Sweden, Norway, and England, answers the same purpose. Litmus paper, so much used by chemists as a test for acids and alkalies, is prepared from the blue dye furnished by this lichen. Whole cargoes of it are annually brought from Sweden to Holland, where its dye, called cudbear, is the most skilfully prepared, and therefore called Dutch blue.

IV. PLANTS FURNISHING VALUABLE BUILDING AND FURNITURE WOODS.

The cultivation of wood is now carried on in several countries in Europe, where the population is considerable and the natural forests have disappeared; above all, Germany is to be distinguished for forest culture. But most wood, especially for ship-building, is still procured from those countries where the natural forests remain—viz., from Russia, Norway, Sweden, Canada, and the United States. In Germany, vast quantities of wood are annually floated down the rivers Rhine, Maine, Neckar, Weser, and Elbe, from the still productive woods of Thuringia, the Hartz, Fichtel, and Erz mountains, and the Black Forest. Russia exports a considerable amount of wood to England and the south of Europe, from St. Petersburg, Riga, Archangel, and from the Russian ports of Odessa and Cherson, on the Black Sea. Much timber is also exported to the south of Europe from Drontheim, Bergen, and Christiana, on the coast of Norway; from Göttenberg, a port in Sweden; and from Dantzic, Konigsberg, and Stettin, Prussian seaports on the Baltic. American timber is exported to the United Kingdom chiefly from Canada *viâ* Quebec, which is a great depôt for wood. The importation in 1867 of timber and wood was:—Not sawn or split, 1,211,042 loads; sawn or split, 2,177,549 loads; and staves, 62,625 loads.

Of forest productions the following deserve to be mentioned as sources of considerable trade:—

Mahogany (*Swietenia mahogoni*, L.; natural order, *Cedrelaceæ*) occupies the highest rank amongst the furniture woods. This is one of the loftiest and most gigantic trees of the tropics. It is indigenous to the West Indies and Central America. The mahogany tree is cut down in April and May, which is the height of the dry season; it is then squared by the adze, the branches being lopped off; and about the middle of June, when the rivers are swollen by the rains, the logs are placed on trucks and drawn by bullocks to the water-side; there they are launched into the river, formed into rafts, and so floated down the stream to the vessels awaiting their arrival.

Spanish mahogany is imported from Cuba, St. Domingo, and the Spanish Main, in logs twenty-six inches square and ten feet long. Honduras mahogany is usually lighter than the Spanish, and is imported in logs four feet square and eighteen feet long. Mahogany is chiefly valued for its colour, firmness, and durability, and the beautiful polish which it is capable of receiving. On account of these and other excellent qualities, it is particularly suitable for ship-building. Mahogany is light and buoyant, free from dry rot, and does not warp; it also suffers less from the action of shot than any other wood; since shot, when received by it, generally remains fast in the wood without splitting it.

Mahogany is extensively used in the manufacture of the best articles of domestic furniture, fancy and ornamental wood-work, cabinet-making and veneering; in fact, there are, comparatively speaking, but few persons who have not this wood constantly before their eyes, in some form or other of useful home furniture. The quantity of mahogany imported into the United Kingdom in 1866 was 53,458 tons.

Ebony (*Diospyros ebenus*, L.; natural order, *Ebenaceæ*).—This tree is a native of the Mauritius. As soon as felled the timber is immersed in water from six to eighteen months; it is then taken out, and the two ends are secured from splitting by iron rings and wedges. Mauritius ebony is imported in round sticks, like scaffold poles, about fourteen inches in diameter. It is much used for inlaying and turnery.

COLOUR.—IX.

By Professor Church, Royal Agricultural College, Cirencester.

COMPLEX COLOUR-COMBINATIONS—HARMONIES OF ANALOGY—HARMONIES OF CONTRAST—HARMONIES OF SERIATION—HARMONIES OF CHANGE.

Hitherto our studies of colours have been confined almost entirely to those which are considered elementary and those which are compounded with equivalents of their constituent primaries. We have only alluded once and again to the existence and use of the vast series of mixed hues. It is, however, chiefly in the employment of those colours that the higher chromatic developments, constituting the poetry of colour, are manifested. The obvious assortments of the primary and secondary colours, with their contrasts, resemblances, and harmonies, are not difficult to understand; but it requires a well-trained eye to discern the subtle differences and concords of composition in which several mixed hues preponderate, and a well-cultivated imagination to appreciate and to pursue their intricate delights. Here, where aid from descriptions is most desirable, it is most difficult. Endeavours to reproduce the more recondite harmonies of hues by mechanical processes are never wholly successful, and usually are even less useful than accurate verbal descriptions combined with references to natural examples. An illustration strikes us as we write. Many an observant student of Nature must have noticed the triple combination of hues presented by an old beech or elm tree as seen against the sky or clouds in early spring. We have the yellowish grey-green of the moss and lichen-grown trunk and branches standing out relieved against the dull grey of the shifting and variable clouds beyond; and this tender green of the moss and grey of the cloud are not flat or uniform, as they too often appear in our imitations of them, but fluctuating with a hundred variations of texture, quality, and tone. A few dead leaves perchance remain, suggesting, if not completing, by their brown or russet hues, the balance of colour, which just needed such idea of warmth and ruddiness as they convey.

But let us regard a little more minutely, a little longer, this natural combination of hues, which we commend, with countless others in the world around us, to every student of decorative art; let us see whether it does not possess other elements of beauty than those which we have recorded. Yes; if we look a little closer we shall doubtless see some delicate portion of nearly pure primary or secondary colour, some stray fragment of brightness—perchance an early flower or insect—just as the ancient pines of the unbroken American forest have been described as bearded with hoary lichens, yet touched with grace by the violets at their feet. So, too, there will be observed in the outermost twigs of our tree that hopeful thickening by myriads of leaf-buds, neither purple-russet nor clove-brown, nor any colour which we can definitely fix, but very beautiful in themselves and promising the verdure of summer. Deep hollows of shade, and the brightness of light will be seen too, yet sparingly, and so, like the simpler colours, made the more precious. From this example, of which nothing but the original work of a master in the art of painting could convey an adequate notion, most important deductions may be drawn. It will help us to realise, in a thoughtful, artistic way, the value of temperance in colour, as well as of balance and distribution. It will lead us to introduce, among our blues and reds and yellows, some of those rarer tints which we cannot exactly name, but which the watchful student of Nature may see trembling on the leaves of the willow, or paving the autumnal paths of the forest, or shining at eventide from the cloudy but splendid pavilions of the sun.

It behoves us now, passing from this somewhat pictorial treatment of the obscure subject of the complex combinations of mixed hues and colours, to attempt the description and classification of harmonies of colour.

It is usual to divide harmonies of colour into two classes—those of analogy and those of contrast. Having already described the conditions under which assortments of colours become more or less harmonious, we need here do little more than illustrate by an example or two the several kinds of harmony of contrast here referred to. But it must be remembered that the distinction of harmonies into two classes is rather arbitrary. Some difference always exists between any two colours and any two tones, so that collocation, whether agreeable or otherwise, inevitably includes the element of contrast. Harmonies differ in degree or in complexity, but not in kind, so far as contrast is concerned. The ordinary harmonies of analogy pass by insensible degrees into distinct undoubted harmonies of contrast. We here cite M. Chevreul's classification of harmonies, a classification which has been adopted by most writers on colour:—

I.—HARMONIES OF ANALOGY.

1. *The Harmony of Analogy of Scale.*—This harmony is essentially the harmony of a series, or the harmony of gradation. It is produced by the simultaneous view of several tones of the same scale, and is obtained in varying degrees of perfection according to the number of the tones present and the intervals between them. When the tones are not easily separable by the eye, and run into one another, then the effect commonly called "shading" is produced.

2. *The Harmony of Analogy of Tones.*—When two or more tones of the same depth, or nearly the same depth, but belonging to different but neighbouring or related scales, are viewed together, the harmony of tone is produced. Many such assortments, however, are displeasing to the educated eye unless they be so selected as to fall into a series with a gradually increasing quantity of some one of their colour-elements, when they may be ranged in the third kind of harmonies of analogy—

3. *The Harmony of a Dominant Colour.*—This harmony is produced by viewing a landscape, a bouquet of flowers, or any contrasted colour-assortment, through a piece of glass so slightly tinctured with a colour as not to obliterate but merely to modify the natural colours of the arrangement or composition.

II.—HARMONIES OF CONTRAST.

1. *The harmony of contrast of scale* is produced by the simultaneous view of two very distant tones of the same scale.

2. *The harmony of contrast of tones* is produced by the simultaneous view of two or more tones of different depths, belonging to neighbouring or related scales.

3. *The harmony of contrast of colours* is produced by the simultaneous view of colours belonging to very distant scales, and assorted in accordance with the laws of contrast. This kind of contrast includes also those cases in which the effect is still further increased by differences of tone as well as of colour.

It must be confessed that the above classification of colour-harmonies is forced and imperfect; for every harmony depends to a greater or less extent upon contrast, either of tone or of colour, or of both; and our harmonies of analogy will be found to be derived from the milder and less startling kinds of contrast. Two ruling ideas will, however, be apparent in colour-arrangements, and upon the recognition of these ideas we may, perhaps, found a more satisfactory classification of colour-harmonies than that of Chevreul. These two fundamental ideas are those of *seriation* and *change*. Of the first we have an example in the assortment yellow, orange, red; of the latter in the assortment yellow, red, blue. Seriation or succession corresponds in some measure to the scales, and change to the chords, of musical composition. Seriation may be succession of tones or of colours, or of both; but in all cases the idea of a series, of steps, of orderly succession, with the presence of a pervading and dominant element, is the leading feature of the arrangement. In harmonies of change, on the other hand, an element common to all the members or a majority of the members is wanting; nor is there any distinct idea of orderly succession or of development in those harmonies which convey very distinctly the notion of change, more or less abrupt. Between harmonies of seriation and harmonies of change there are numberless connecting links, so that the one kind may imperceptibly slide into the latter. For beyond the regulating principles of balance, distribution, appropriateness, harmony, etc., no rigid rules, as of cast-iron, need trammel the imagination of the colourist, and so no precisely-defined classes can be arranged to receive all the possible harmonies of assorted colours and hues. What further remarks we have to make with reference to this subject we now proceed to give under the two heads of harmonies of series and harmonies of change.

Seriation, succession, development, sequence, gradation, or shading include many cases of the harmony of analogy, and are of two kinds. The tones of a scale succeeding one another in regular order furnish one example of shading; another is seen in a series of assorted colours so arranged as to convey the notion of a gradual increase of some quality in the series. The gradual development of the full leaf-green of a plant in the spring furnishes an example of gradation, not only of tones but of colours. A greenish-yellow passes into yellowish-green, this into green, and this finally acquires both depth and a greater proportion of blue. Leaves in autumn may often be observed to reverse this order, passing through various tones and hues of russet, red, orange, and yellow. The open country continually offers illustrations of the two kinds of gradation we have named, and the landscape painter, apprehending the value of this fact, is enabled to realise the relations to each other of the different parts of the view spread before him, both as regards gradation of tone and gradation of colour. In the near objects constituting the foreground he notices the extensive range of the scales both of tone and colour, and the preponderance of those hues which imply the notions of brightness and warmth. In the middle distance the range of tones and colours is more abridged; while the far distance is commonly distinguished by retiring and cold colours, with a very limited range of scale as well as of colour. From these natural examples of gradation we may take many hints useful in applying colour to decorative purposes. Supposing we wish to conventionalise a compound leaf according to the principles laid down in the "Principles of Design," we may do so not only so far as its details and form are concerned, but also in reference to its colour. Fig. 15 represents such a conventional colour arrangement—an arrangement the key to which is to be found in a natural sequence of colours often occurring in plants.

What is called a harmony of analogy runs through the series of colours in Fig. 15. The four colours there assumed to be present resemble in kind and in order those found in the spectrum of the sun to lie between the yellow and the green. The arrangement of the series conveys the idea of an increasing brightness and warmth as we descend from the pure green terminal leaflet to the smallest pair of leaflets close to the leaf-stalk. Fig. 16 represents the same series of colours in a diagrammatic way, but inverted, and furnishes us with a scientific analysis of the effects observed. The full green is represented, in accordance with the common theory, at the base of Fig. 16 as containing eight parts of blue and three of yellow. The yellowish-green comes next, with one-third less blue and the same amount of yellow as before. The greenish-yellow contains only one-third the amount of blue of the original green. Then we reach the pure yellow, which is to be regarded as the common element of the series, bringing all its members into relation.

In our next illustration (Fig. 17) the range of colour is more extensive. The series is not for general use in decorative assortments, but there are several useful lessons to be drawn from it and applied in practice. The contrasts between contiguous colours in the present example are much more startling than in Fig. 15, the intervals are larger, while the harmony is one which must be said to lie between those of analogy and those of contrast. The element of serial succession or development is weak here, that of change very apparent. The gradation in the assortment depends upon the increasing brightness of the colours as we ascend, and upon the link which connects each group of three neighbouring colours together—the presence of a common element. We arrive at this result by interposing a secondary between its constituent primaries all through its arrangement. Thus orange is placed between yellow and red, which latter is succeeded by violet, the compound of red and blue. Blue follows, and after this green; then we should re-commence the series by returning to the yellow with which it began. The analysis of the colour-series in Fig. 17 is represented roughly in Fig. 18, where the thin lines represent yellow, a thicker line red, and the thickest line blue. Where two lines overlap, a compound colour appears.

We may, however, learn something more from Fig. 17 than is here put down. The greater development of the stalks and leaflets towards the base, with the gradually increasing pointed character of the latter towards the summit, helps to carry out the idea of series suggested by the succession of the colours. If in some minor details, such as the larger size of the second pair of leaflets, we find a break in the symmetry of the series, this is just the common feature of vegetable and animal growths by which they are in part distinguished from the mathematically accurate, but less interesting products of mere mechanism; for very often the poetry, the mystery, of beautiful organic forms lies hid in such seeming exceptions to law.

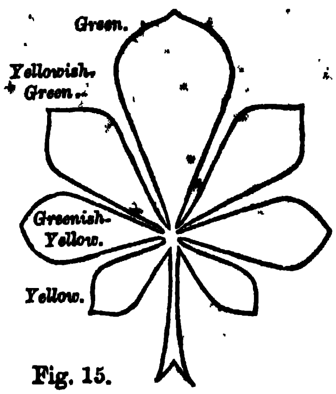


Fig. 15.

We must not fail to notice that there exist several methods of more completely harmonising the contrasted colours of such a series as that shown in Figs. 17 and 18. In copying the former figure in colours for the sake of the instruction this exercise affords, we recommend our readers to try the following generally applicable methods of bringing greater unity into such a series:—

1. An outline and veining of black, common to all the leaflets.
2. An outline and veining of gold, common to all the leaflets.
3. The addition of grey to the whole of the colours used, the largest proportion being added to the green, the least to the yellow.
4. Instead of making the secondary colours by mixture, introduce their constituent primaries by dots placed side by side.

Splendid examples of such gradations of colour as those we have been describing are to be found in numerous specimens of decorative art and manufacture in the fabrics of India,* the silks of Damascus, the *faience* of Persia, the lacquer-ware of Japan, and the porcelain of China. To take a single example, we may refer our readers to the peculiar but beautiful selection and sequence of colours upon such plates of the so-called "Persian ware" as may be seen in the Ceramic Gallery at South Kensington. The particular variety of this ware which we have now in view is known as "Damas," "Lindus," or more generally "Rhodian." The range of colours is limited except so far as one series is concerned—the series beginning with green, and passing through turquoise blue, to a pure deep cobalt, and thence to a lilac hue. The most conspicuous of the remaining colours is a dull brick-red, opaque and much raised in relief above the others. A chocolate brown, and a black or grey like that of Indian-ink complete the list, except that now and then a specimen of the ware is found with a little yellow on it. On a ground of creamy white, conventionalised forms derived from the hyacinth, the tulip, and a few other plants occur. The leaves are filled in with a copper-green, some flowers are of deep blue touched with turquoise, others of a lilac hue. On some specimens no other colours are found than these four, yet these establish so lovely a series that it is doubtful whether the specimens which exhibit these colours only are not equal or even superior to the others. The colours of the plants represented probably suggested, in cases like the present one, some of the predominant harmonies in which the dull red, with its yellowish tincture, balances the cooler blues and greens, while the Indian-ink colour, in light circles and delicate spirals of smoke-grey, tones down the whole composition, and actually brightens and purifies its dominant series of colours. We ought not to fail to notice a most precious quality of these Persian wares—that fluctuation of colour, that absence of mechanical hardness of outline and uniformity of tone which distinguishes human handiwork of the thoughtful kind from the perfectly correct and thoroughly insipid work of a machine. But we must not linger any more over our illustrations of the harmonies of series or relation, but conclude our present lesson with a word or two on the "harmonies of change."

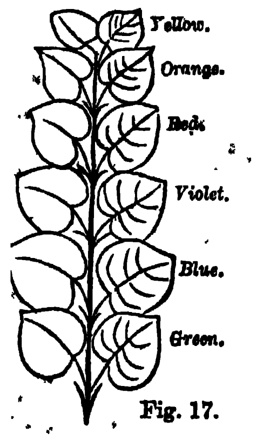
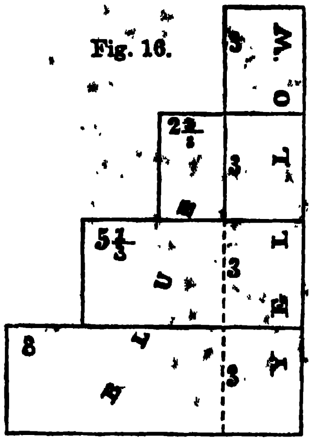


Fig. 17.

Fig. 16.



Harmonies in which the sequence or relationship of the constituent colours is indistinct or absent include most varieties of the harmonies of contrast. The change of tone or colour in them may vary greatly in abruptness: in the more complex assortments of this class it is very difficult to attain anything like an agreeable unity, for if there be many startling changes or contrasts, the effect becomes tiresome and spotty. The harmonies of change become more agreeable the more closely the rules of judicious distribution and balance of colour and tone are followed. The free use of separating lines of white, grey, gold, or black is often indispensable. The value of reduced tones of colour, and of the mixed and tertiary hues to modify the crudeness of a startling contrast, is very remarkable. But we have already described at considerable length, in Lessons V., VI., and VII., the principles upon which harmonious contrasts depend, and so here simply confine our attention to two illustrative examples derived from the floral world.

We might turn to the splendid family of the orchids, with their quaint forms and complex systems of colour, or we might choose one of the *Malvaceæ*, such as the *Abutilon megapotamicum*—a plant in which the green of the leaves offers a violent contrast with the red of the swollen calyces, and the five bright yellow petals of the corolla contrast again very forcibly with the violet hue of the central branch of clustered stamens—a startling assortment, but very rich in effect, when completed by the opening of the flower. In this example, besides the mere notion of contrast, we have the idea of repetition which resembles that of seriation; red contrasting with its complementary, green, and yellow with its complementary, violet, both the complementaries having, therefore, the third element, blue, in them. But every flower presenting three different colours may serve to illustrate the harmony of contrast, and we need not go far for an example. Even the quiet violet with its minute orange-tinted eye, the faint green bases of its petals and their own chief hue, somewhere between blue and red, affords a colour-assortment of the kind under discussion, the balance of which is in a measure completed when the leaves of the plant are included in the series. Similar studies of other plants should be made; it will surprise many persons to discover what a world of instruction, as well as of enjoyment, is to be derived from what we may call the chromatic analysis of flowers.

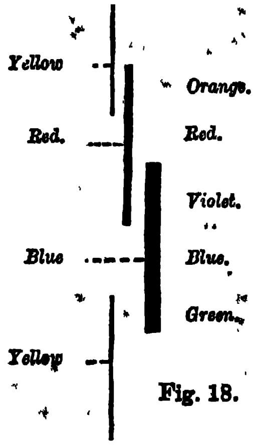


Fig. 18.

The next subjects to be discussed are the modifications of colour arising from methods of illumination and differences of structure and surface.

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* See, for the important lessons to be drawn from the study of Oriental fabrics, Dr. Dresser's seventh paper on "Principles of Design" (Vol. I., page 230).

THE STEAM-ENGINE.—VII.

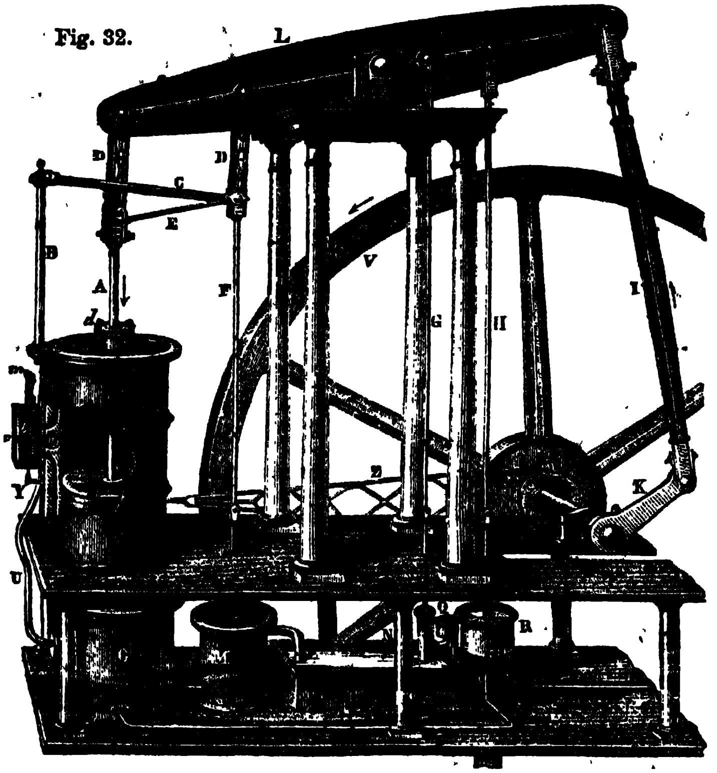
By J. M. Wigner, B.A.

BEAM—PARALLEL MOTION—CRANK—FLY-WHEEL—ECCENTRIC.

As we said in our last lesson, we shall first describe the construction of a condensing beam-engine; and Fig. 32 represents a model showing very clearly the construction and action of the different parts of an engine of this kind. In an actual engine the arrangement of the condenser, hot-well, and pumps shown on the lower base is often very considerably modified, so as to suit the exigencies of the special case, but their action is not in any way altered by this change.

A portion of the side of the cylinder is here shown removed, so as to exhibit clearly the piston and slide-valve which we have already described. L represents the "working beam," which is made very strong, and is usually of great weight. A pivot passes through its centre point, and turns in bearings supported by stout iron pillars, or, as is more commonly the case, firmly built into the masonry of the engine-house. This beam is carefully balanced, so that it may oscillate on its bearings without a great amount of force being required.

Fig. 32.



The piston-rod, A, imparts motion to one end of this, and at first sight it might seem sufficient merely to fasten it by means of a pin or a common joint. We must remember, however, that the piston-rod has to move vertically up and down, and, as we shall easily see, the point of attachment to the beam moves in an arc, and does not, therefore, remain vertically over one spot. If, then, it was fastened in this way, the piston-rod would at once be bent, so that it would not act. The plan originally adopted to obviate this consisted in fixing an arc to the end of the beam, and attaching the rod to this by means of chains. This plan, however, was very clumsy, but the difficulty is fully met by the beautiful contrivance invented by Watt, and known as Watt's Parallel Motion. The piston-rod here is jointed to a compound rod, D, the other end of which is jointed to the beam.

A similar rod, also lettered D, is affixed to the beam a little way from the end, and a rod, E, is jointed to the end of these, so that a parallelogram is formed by the three rods and the portion of the beam between the pivots. The most important part of the arrangement is another rod, C, which is jointed at one end to a wall-plate attached to the building, or else, as in the figure, to a firm upright, B, affixed to some convenient part of the engine, and at the other end to one of the lower angles of the parallelogram. As will easily be seen, when the beam is nearly at the end of its oscillation, the pivots in it are nearer the centre line than when it is horizontal; the rod C, however, at those times pulls the lower ends of D, D in the other direction; and thus, when the lengths of the rods are carefully adjusted, A moves up and down in a perfectly vertical line.

To the other end of the beam the connecting-rod, I, is affixed, which imparts motion to the driving-wheel of the engine. This is accomplished by means of a crank, K, affixed to the axle of the wheel V. The connecting-rod, I, is fastened to the end of K, by a pin passing through both, and turning freely in one. When in the position represented, the end of the beam to which the connecting-rod is attached is rising, and it accordingly raises the end of K, and sets the wheel in rotation. As soon, however, as the stroke of the piston is completed, and this end of the beam is at its highest point, the connecting-rod, I, and K will be in the same straight line, and it is clear that then any pressure, whether up or down, will merely be transferred to the axis of V and the bearings in which it turns, and cannot in any way tend to turn the wheel. At this point, indeed, the crank loses all its power, and ceases to act. This is apparently a great drawback, and at first sight we should suppose that it would cause the motion of the engine to be very irregular and uneven. The difficulty, however, is easily overcome. The wheel V is made with a very heavy rim, and this serves as a kind of reservoir of force. When the crank is in its most advantageous position, the tendency is to increase the speed of the engine; owing, however, to the weight of the fly-wheel, a very slight increase is produced, the power being as it were stored up in the form of momentum imparted to the wheel, and this momentum urges it past the "dead-points" as they are called, and thus renders the motion for all practical purposes quite uniform.

It is manifestly a thing of considerable importance to have the weight of the fly-wheel so adjusted as to bear a due proportion to the power of the engine. If, on the one hand, it be too heavy there will be a needless addition to the load of the engine; while if, on the other hand, it be too light, the motion will not be uniform. The practical rule is that the power stored up in it should be about equal to that produced by 6 half-strokes. Thus, if the steam exert a pressure of 1 ton on the piston, and the length of the stroke be 4 feet, the power thus generated is 6 × 4 × 1, or 30 tons. The weight and velocity of the wheel should therefore be so arranged that its momentum is about equal to this. If, then, the weight of the rim be 1 ton, its velocity should be that which would be acquired by a body falling 24 feet; if it weigh 1½ tons, it should be that acquired in falling 16 feet, and so on in proportion.

The machinery to be set in motion is usually driven by a strap passing round the fly-wheel, and then round the driving pulley of the shafting. In some cases cog-wheels are employed in place of the straps to drive the first motion.

Z is the eccentric by which motion is imparted to the slide-valve. On the axis of the fly-wheel a circular disc of metal, *e*, is keyed in such a way that the axis does not pass through its centre, but considerably to one side of it. A ring of brass surrounds this, so affixed that the disc can turn freely inside it, but cannot slip out. The rods at the side of Z are fastened to this ring, and thus as the axle rotates, carrying the disc with it, the ring is alternately moved to the right and to the left, and imparts this alternating movement to the eccentric. Behind the cylinder, and hidden by it, is a bent lever, one end of which is jointed to Z, and the other to the valve-rod, *m*; and by means of this the alternate movement of Z moves the slide-valve and regulates the supply of the steam.

The steam-pipe is omitted in the figure, but it enters the valve-casing as in Fig. 31, and the exhaust leads to the condenser O, seen under the cylinder, where the waste steam is condensed, and a vacuum thereby produced. In this way there is scarcely any resistance on the exhaust side of the piston, and the full pressure of the steam is communicated to the beam through the piston P and piston-rod.

The description of the remaining portion of the steam-engine must be deferred to our next lesson.

APPLIED MECHANICS.—X.

BY ROBERT STAWELL BALL, M.A.,
Professor of Applied Mathematics and Mechanism, Royal College of Science, Ireland.

THE SHEARING MACHINE AND PUNCHING MACHINE.

In the last lesson we briefly described the most important tools used in the manufacture of wrought iron—namely, the steam-hammer and the rolling mills. In the present lesson we shall describe the other tools which are of the utmost utility in the subsequent treatment of wrought iron.

The plates of iron which are produced by the rolling-mills are destined for various purposes. The best of them are employed for boilers; others are used for making iron ships, iron girders, and multitudes of minor uses. The iron plates for which the punching and shearing machines are used vary in thickness from ordinary sheet-iron up to nearly an inch in thickness.

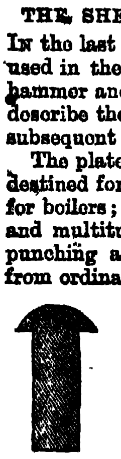


Fig. 1.

The shearing machine, as its name indicates, is employed in trimming the edges of plates, and in cutting them to the required sizes. The punching machine is employed for the purpose of making holes in the plates, by which they can be attached together with rivets. The usual form of rivet is shown in the annexed figure (Fig. 1). It consists of a cylindrical shaft, at one end of which is an hemispherical head. The rivet is heated red-hot, and is passed through holes in the plates which are to be united together. The workman then strikes the projecting cylindrical end with a hammer, while his assistant holds a heavy weight against the head to prevent the rivet being driven out by the blow. A second hemispherical head is thus formed on the projecting end while the rivet remains red-hot, and as it cools, the contraction of the red-hot iron draws the plates together with prodigious force. The appearance two such plates present when riveted together is shown in Fig. 2.

Since this is the universal method of attaching iron plates to each other, it follows that some convenient and rapid method of producing the necessary holes in the plates is a matter of necessity. This will be evident if we remember that very many thousands of such rivets are used in the construction of an iron ship, and each rivet requires two, or sometimes a greater number of holes.

To meet this want the punching machine has been devised. It is somewhat varied in form, to meet the exigencies of different manufactures, but it is substantially in all cases a combination of two distinct mechanical principles, the fly-wheel and the lever. The latter we have already considered, and it will now be necessary to give a description of the former, and an account of the mechanical principles upon which its use depends.

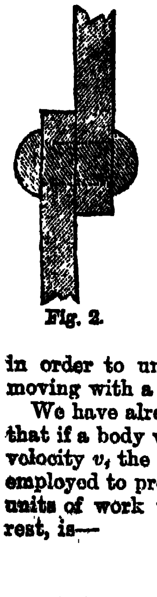


Fig. 2.

The fly-wheel is generally a cast-iron wheel, with a very massive rim. It is mounted on an axle, and has motion communicated to it by a steam-engine. The fly-wheel is strictly a reservoir of power. It is a store into which the engine pours its energy, to be withdrawn, as occasion may require, by the machine which is in use. A little consideration will be necessary in order to understand the amount of work that a fly-wheel moving with a given velocity is capable of storing up.

We have already explained in the lesson upon the hammer, that if a body whose mass contains m pounds be moving with a velocity v, the number of foot-pounds of work which have been employed to produce this velocity, and therefore the number of units of work that this body will give out before it comes to rest, is—

$$m\frac{v^2}{64}.$$

We shall now apply this result to determine the number of units of work in a revolving fly-wheel.

Let n be the angular velocity of the fly-wheel. The angular velocity of a body is the number of angular units through which it turns in the unit of time. Thus, for example, if we say the angular velocity of a body is 3, what is meant is, that it turns through three times the angular unit in one second. Now it will be seen, by referring to the lessons in Trigonometry, that the angular unit is 206,265 seconds; and therefore, when a body has an angular velocity of 3, it turns in one second through 206,265 × 3 seconds, and dividing this quantity by 60 × 60, we find the number of degrees through which the wheel will move in one second.

It follows, from the definition of angular velocity, that if R be the radius of the wheel, the actual velocity of any point on its circumference is nR.

If the wheel be large, we may, without appreciable error, assume all points in its rim to be moving with the same velocity.

Let m be the number of pounds in the rim. Then the mass m is moving with the velocity nR, and therefore the total quantity of work stored up in the wheel when revolving is—

$$m\frac{n^2R^2}{64}.$$

In order to give an application of this formula, we shall apply it to the following problem:—

A fly-wheel twelve feet in diameter, whose rim weighs four tons, revolves four times in a minute. It is required to determine the number of units of work which it contains.

Since the wheel turns round once in fifteen seconds, its angular velocity is—

$$\frac{2\times 22}{15\times 7}=0\cdot42.$$

Therefore the velocity of the rim is—

$$0\cdot42\times 6=2\cdot52.$$

We have then a mass of four tons moving with a velocity of 2·52 feet per second. The quantity of work stored up is therefore—

$$8960\times\frac{(2\cdot52)^2}{64}=889.$$

Hence 889 units of work must have been expended in order to get up this speed in the wheel, and a similar quantity will be given out before the wheel can come to rest.

It is usual, however, to give the fly-wheel a much higher velocity than in the example we have taken; and the higher the velocity, the greater the quantity of work. This will be evident from the expression for the work, viz.—

$$m\frac{n^2R^2}{64};$$

for this varies proportionally to n^2—that is, to the square of the angular velocity.

Hence, if we increase the speed of a wheel to double its amount, we quadruple the quantity of work that it contains. If the wheel we have been considering revolved twenty times in a minute instead of four times, the quantity would be increased 25-fold, and would become 25 × 889 units. The fly-wheel which is used in connection with a punching machine is small, but revolves with a very high velocity, and so is capable of holding a large store of work.

Let us suppose a wheel of 2 feet in diameter, whose rim weighs 2 cwt., and revolves five times in a second. The angular velocity is therefore—

$$10\times\frac{22}{7}=31\cdot4.$$

Hence the quantity of work stored in the wheel is—

$$224\frac{(31\cdot4)^2}{64}=3451.$$

This wheel is therefore capable of raising a load of 3,451 lb. through one foot before it comes to rest, or a pressure exceeding two tons must be exerted through one foot by machinery connected with this fly-wheel before it is brought to rest.

We shall now be able to understand the use of a fly-wheel in machinery which, like a shearing machine, has occasionally to overcome a very large resistance. The engine accumulates a vast store of its energy in the rapidly revolving fly-wheel. Before the machine which experiences the resistance is in action, the motion of the fly-wheel becomes accelerated. When the machine comes into action one of three things must happen; the fly-wheel must be stopped, or the machine must be broken, or the resistance must be overcome. But the fly-wheel cannot be stopped until it has poured forth all the energy which it contains; and, of course, the dimensions of the fly-wheel and its velocity are so proportioned that its store of energy shall be ample for the work. Nor can the machine be broken; for machines of this class are always very massive, in consideration of the vast strains to which they are liable. It follows, therefore, that the resistance must be overcome.

The general appearance of a shearing machine will be understood from Fig. 3, which is the representation of one of the simpler machines of this class. It consists of a long lever of the first order, A C B, which has its fulcrum at C, the centre about which it turns, while the power is applied at the end A, and the resistance is encountered at the end B. At the end A is a roller, which turns around an axis, and is a means of diminishing the friction, which would otherwise be inconvenient. The roller, D, is acted upon by a cam, F. This cam consists of a circular piece of iron, which is mounted excentrically at H. As the axle H revolves the cam gradually elevates the roller, and thus applies the power to the extremity of the lever. After the roller has reached its greatest height, the weight of the lever is sufficient to bring it down when, by the revolution of the cam, its descent is possible. In this way the continuous rotation of the cam gives a reciprocating movement to the lever. At the back of the cam is shown the fly-wheel, F′. This is mounted on the same axle, H. The engine, or other source of power, which gives motion to the axle, is not shown in the figure. At the end B of the lever is one jaw of the shears, K; the other, L, is firmly attached to the stand. Whenever the roller D is raised, the jaws are closed, and the piece of iron or other body that lies between the jaws is severed.

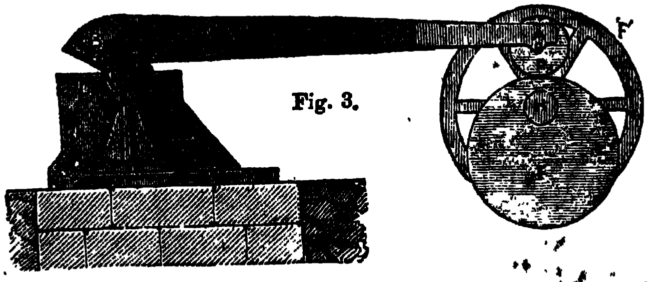


Fig. 3.

Let us suppose that a bar of wrought iron one square inch in section is required to be sheared across. It has been found, as the result of numerous careful experiments, that an average pressure of about 20 tons is necessary. It is very remarkable that this is about the same force as would be required to tear the bar across by extension; a little consideration will, however, point out why this should be so. In each case the same number of particles of iron have to be separated from each other.

On the scale which we have used for the figure the mechanical advantage of the lever is about six-fold. Hence it will be necessary that the end A of the lever be pressed upwards with a force of about 3 tons, or a little more, in order to cut the bar across.

We shall also be able to form an estimate of the number of units of work which will be absorbed from the fly-wheel in the operation of shearing. A pressure of 20 tons—that is, of

$$20 \times 2{,}240 = 44{,}800 \text{ pounds}$$

—has to be exerted through a certain distance. It is not very easy to ascertain what that distance is; it must be less than one inch. This will be evident from Fig. 4. In this A B are the edges of the shears; C D is the bar which is exposed to their action. Now it is evident that almost immediately after the cut of the shear commences the iron must be divided completely across; hence the force has only to be exerted through a space which we may certainly assume does not exceed one quarter of the total thickness to be cut. The force of 44,800 pounds has, therefore, only to be exerted through the space of $\frac{1}{48}$th part of a foot; consequently the total number of units of work is—

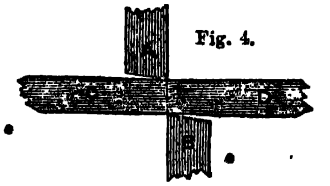


Fig. 4.

$$\frac{1}{48} \times 44{,}800 = 933.$$

Hence, for each operation of shearing, a number of units of work not exceeding 1,000 is abstracted from the energy stored up in the fly-wheel.

The operation of punching is in many respects analogous to that of shearing; in fact, punching consists in shearing out a cylindrical piece from a plate of iron. The important part of a punching machine will be understood from Fig. 5, in which A B is the plate of iron through which a hole is required to be made; P is the punch, which is made of hardened steel; C D is the block, and E the recess into which the piece of metal is forced from the plate.

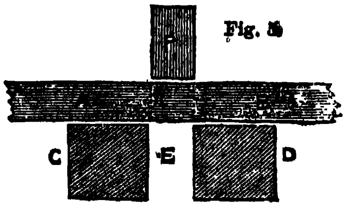


Fig. 5

The punch, P, is depressed, by means of a fly-wheel cam and lever, in a manner analogous to the shearing machine; the quantity of work absorbed in punching a hole can also be estimated in the manner already described.

TECHNICAL DRAWING.—XXVIII.

DRAWING FROM ROUGH SKETCHES (*continued*).

In this lesson some further examples are given with the view of affording the student additional practice in setting out work to a scale, instead of merely measuring the lines from copies.

It is again, however, necessary to mention that these are *rough* sketches, such as might be given by the head-engineer (though these would in most cases be rougher still), or as might be taken from the object, to be afterwards made into correct drawings.

The proportions are only, therefore, *generally* correct. The figures, not being drawn to any particular scale, must not be depended upon as *copies;* the subject is, therefore, to be worked according to the measurements marked upon them.

Fig. 260 is the head of a *connecting-rod* of a locomotive passenger engine.

The construction of connecting-rods generally will be found in the lessons describing the details of an engine. It is only, therefore, necessary in this place to give the names of the parts and the method of drawing them.

A is the rod-end; B, the end of the axle; C, the outside of the brasses; D, inside of the brasses; E, oil-cup; F, cotter; G, gib; H H, set-screws to keep the cotter from moving.

As usual in all objects which are symmetrical, a centre line should be first ruled.

Starting, then, with the line *a b*, and this having been made 4½″ on each side of the centre line, the complete block forming the head of the connecting-rod is to be drawn.

The arc at the top is struck from a centre situated at *c*, whilst its meeting with the sides of the block is rounded off by two smaller arcs struck from *d*, *d*.

The lines forming the inside and outside of the brasses are now to be drawn, and the axle-end, the centre of which is 7½″ from *a b*, and the radius of which is 2″.

The oil-cup, gib, cotter, and set-screw will now follow, and the line *a b* is to be united to the rod-end by arcs. This example should be drawn to the scale of 6 inches to the foot, or half real size.

Fig. 261.—The subject of this lesson is a section of a *stop-cock*, drawn to about half the real size.

A stop-cock is an arrangement by which gases or liquids are allowed to pass, or are at pleasure prevented passing, through pipes, or from any receptacle in which they may be contained. They consist of A, the cock, B, the plug, and C, the handle, which in some cases forms the upper portion of the plug, placed at right angles to its axis, and in others (as the present) is simply a lever pierced with an aperture of the same shape at the top of the plug, which may be removed when desired.

Stop-cocks are generally made of brass, composition metal, or cast iron. The cock is formed with or without flanges for attachment to different pipes, vessels, boilers, etc. The above example terminates in a screw working in a plate. In this view the tap is turned "on," so that the hole through which the liquid would pass is shown in dotted lines.

The plug is conical, so as to fit better in its seat, the part which receives it being turned out so as to correspond with the conical surface. The plug is also kept in its place by a nut D, working in a screw formed on its lower end, E.

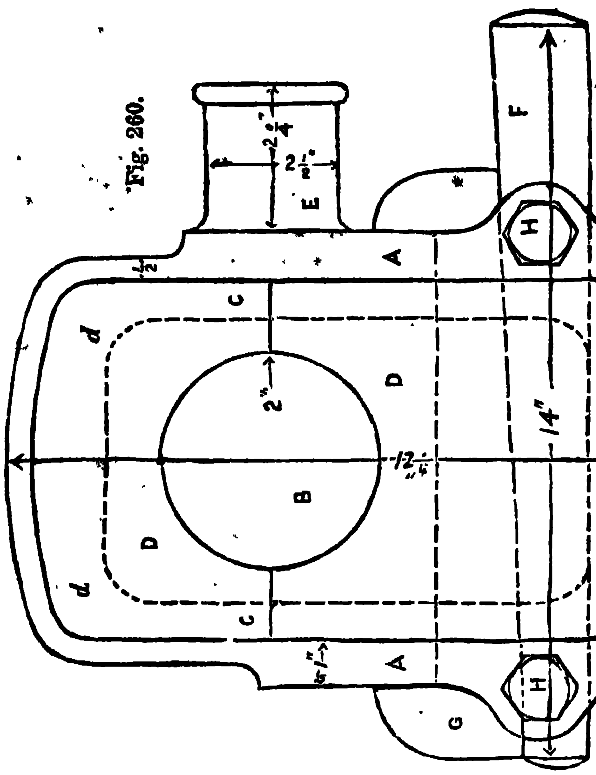


Fig. 260.

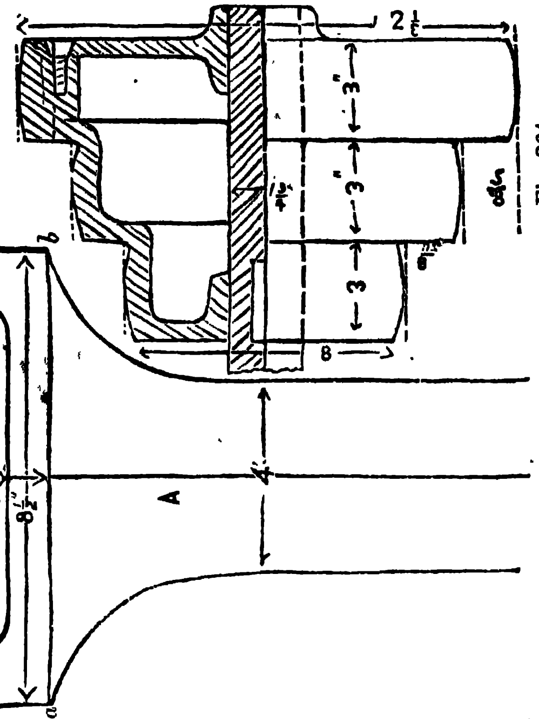


Fig. 264.

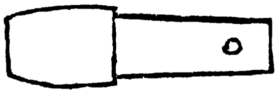


Fig. 263.

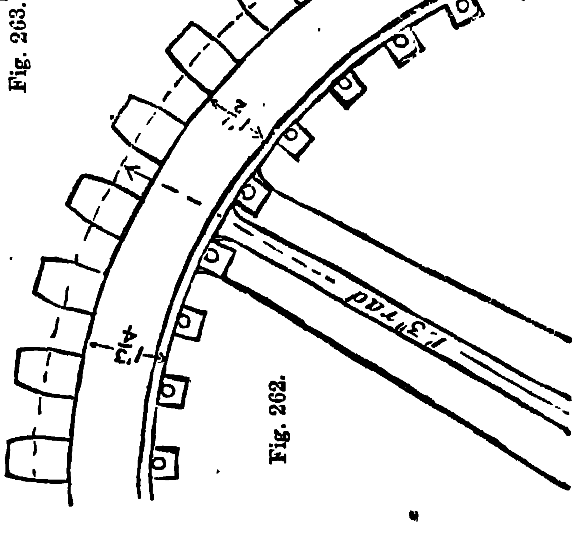


Fig. 262.

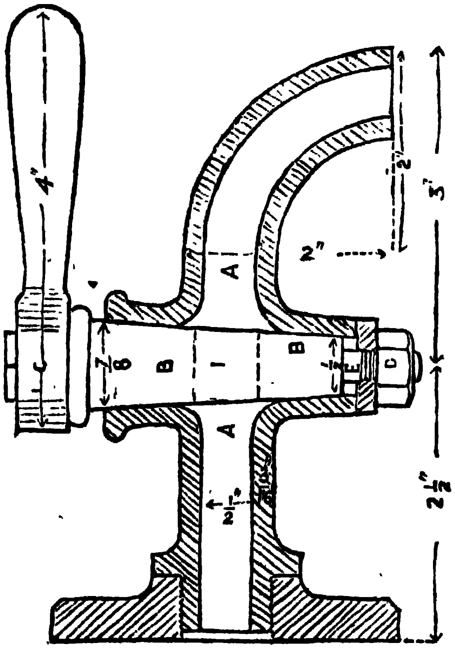


Fig. 261.

Having drawn the perpendicular from the back of the plate into which the cock is screwed, and also a perpendicular for the central line of the plug at 2½" from it, draw the external lines of the straight part of the tap; these merge into the quadrant struck with a radius of 2".

The plug is now to be drawn; its length without the flange at the top, and the screw at the bottom, being 2¼ inches; its greatest width, ⅞", and its smallest width, ½ an inch. The handle-flanges and other details will now follow and complete the subject. The thickness of the metal is $\frac{3}{16}$. This stop-cock should be drawn to its full scale.

Fig. 262.—This is part of a *cog-wheel*—a name generally understood to mean a wheel in which the teeth are made of wood and mortised separately into an iron rim, in contradistinction to *spur*-wheels, in which the teeth are of iron, and form a part of the rim itself. These wheels were in general use in large machinery before the introduction of cast-iron wheels, and are still very common in mills. The cogs are kept in their places by pins placed inside the rims, or by keys placed between their ends. In regard to such wheels, Professor Willis says ("Mechanism," art. 55):—

"The above construction of a toothed wheel has been partly imitated in modern mill-work, for it is found that if in a pair of wheels the teeth of one be of cast-iron, and in the other of wood, that the pair work together with much less vibration, and consequent noise, and that the teeth wear each other less, than if both wheels of the pair had had iron teeth.

"Hence, in the best modern engines one wheel of every large-sized pair has wooden cogs fitted in it in the manner just described, only, instead of employing a wooden wheel to receive them, a cast-iron wheel with mortises in its rim is employed."

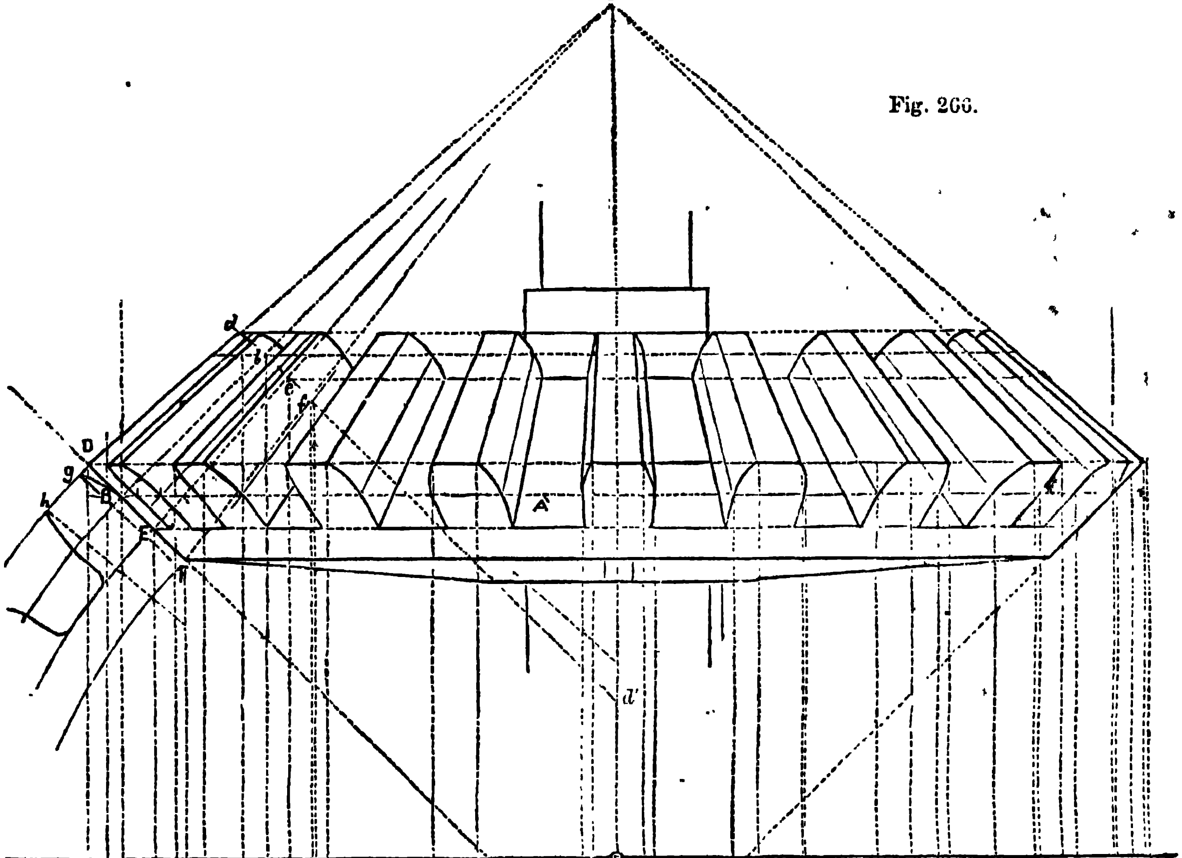


Fig. 266.

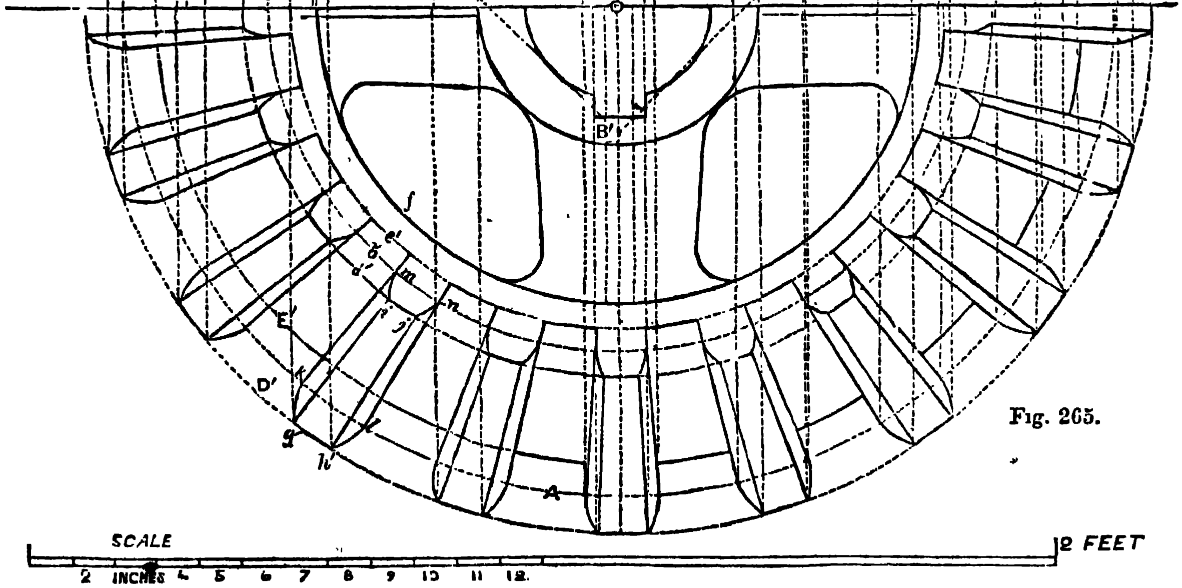


Fig. 265.

In the present example the radius of the pitch is 1′ 3″: there are 6 arms and 48 teeth. This study should be worked to the scale of 3″ to the foot.

One of the cogs is separately shown on an enlarged scale in Fig. 263.

Fig. 264.—This is a half-elevation and half-section of a *cone-pulley*, or speed-pulley. As the action of this arrangement will be fully detailed in relation to lathes, it will only be necessary to give a few hints as to the method of working out the subject. Having drawn the centre line of the shaft, set off three separate spaces of 3″ each, for the widths of wheels composing the cone. The first of these is 1′ 2½″ in diameter, and the radius of the others decreases by ⅜ in each case.

The form of the edge of each pulley is slightly convex, in order that the strap may remain upon the discs, the tendency of the belt being to rise higher rather than to slip off.

The section shows how the interior of the cone is cast, the angles being rounded in order to strengthen it. The back plate is attached by screws working in solid pieces of metal cast in the rim of the larger pulley.

This subject should be drawn to the scale of ¼ of an inch to an inch.

MECHANICAL DRAWING (*continued*).

Fig. 265 is the plan, and Fig. 266 is the elevation, of a *bevel-wheel*.

It will be easily understood that, although spur-wheels are employed to transmit motion from shaft to shaft, they can only do so when the shafts are parallel to each other.

When the shafts are inclined, or form any angle with each other, the wheels must become portions of cones to roll on each other, and are called *bevel-wheels*.

In order that such wheels may work accurately, the shafts or axes of any pair working together should be situated in the same plane; in this case the axes will meet in a point which will be the apex common to both the cones of which the bevel-wheels are portions.

It is sometimes, however, convenient that the axes of the bevel-wheels should pass close to each other, without intersecting: they are then known as *skew-bevels*.

When the cones are equal and the axes are at right angles, they are called *mitre-wheels*.

In Fig. 265, A is the pitch-circle, or base of the cone of which the mitre-wheel is to form a frustrum; and in Fig. 266, A′ is the elevation projected by perpendiculars from it.

From both ends of the line A′ (as B) draw lines at 45°, meeting in a point B′ on the central perpendicular.

Now with radius B′ B describe an arc which will be a portion of the development of the cone forming the underneath side of the bevel-wheel; each bevel-wheel being, as it were, made up of frustra of two cones meeting the point of the teeth; the apex of the one being at B′, and of the other at C, obtained in the same manner, by drawing lines at 45° to the elevation of the pitch-circle.

Divide the pitch-circle, A, in the plan into pitches, and set off in these the teeth and spaces. At B, draw a tooth as it would really be if the surface of the cone were developed or spread out.

Lines drawn from the point, the root, and base of the rim to C, will give the points D, E, and F on the line B. From these points draw horizontal lines which will give the elevations of the circles on which the points and roots of the teeth will be situated, and of the base of the rim.

Project the elevations D and E on the plan—viz., the semicircles D′ and E′. The plan of the circle of which F is the elevation, F not being required in this view, is omitted.

From D (on each side) draw a line to the apex, C, and on this set off D *d*, the length of the teeth. This is generally taken at two, or two and a half pitches (the former in the present example).

From *d* draw a line parallel to D F—viz., *d d′*. From B, E, and F draw lines to C, cutting *d d′* in *b*, *e*, *f*. From these points draw horizontals, which will give the elevation of the pitch-circle, points, and roots of the teeth at the narrow end of the bevel-wheel. Project these into the plan, and so obtain the semicircles *d′*, *b′*, *e′*, *f′*.

Set off within the teeth around the circle D′ in the plan, the width of the point *g h*, taken from the developmen tshown at the side of the elevation—viz., *g′ h′*—and from these points draw lines to the centre of the plan; these radial lines extending only between the circles D′ and *d′*, as *g i* and *h j*.

Join *g′* and *h′* by means of arcs to *k* and *l* (the widths of the teeth already set off), and from *k* and *l* draw as far as the circle *e*, the root of the teeth, passing through the pitch-circle of the upper end of the teeth in *m n*.

Join *m* and *n* to *i* and *j*, and this will complete this portion of the plan.

It only remains now to project all the points of teeth, as *g′ h′*, on the line D (Fig. 266), by carrying up perpendiculars from the plan to meet the corresponding lines in the elevation. This is shown by dotted lines in the illustration. The arms and shaft are then to be added in plan and elevation.

A scale of feet and inches is appended to Figs. 265 and 266, from which the diagrams have been constructed, and which may be used by the learner to ascertain the relative dimensions of the different parts of the bevel-wheels as shown in the diagrams. His own drawing, however, should not be made from the scale that we have given, but from one of his own construction, the measurements in the diagrams being ascertained from our scale, and then made in his own drawing from his own scale.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VII.

By Professor Wrightson, Royal Agricultural College, Cirencester.

WATERING LAND BY ARTIFICIAL MEANS.

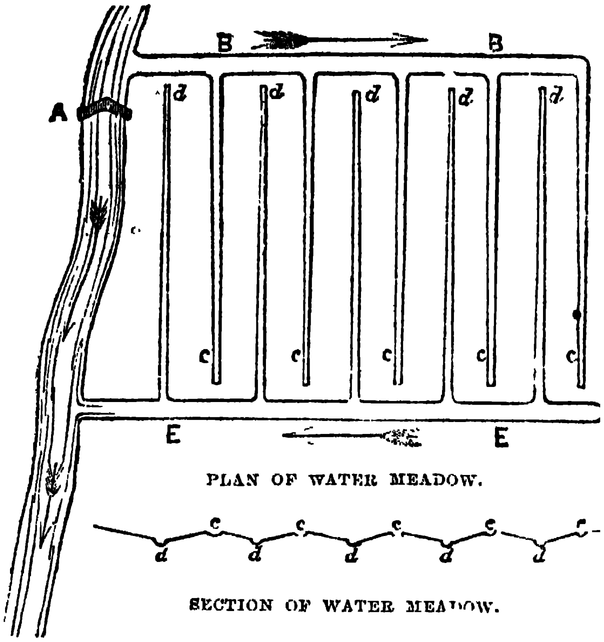
That the practice of irrigating, or artificially watering land, has been practised from the most ancient times, there is no doubt. It would occupy more space than we can afford, as well as carry us into questions which it is not our object to discuss, had we to give a detailed history of the art. It must, therefore, suffice to mention that in Egypt, where the annual overflow of the Nile early taught the lesson, in Persia, in Palestine, as well as in India and China, and later, in Roman agriculture, irrigation occupied an important place. In hot and arid countries, indeed, it is positively essential, while in the more temperate climates of Western Europe it is a valuable means of increasing the productiveness of land. This practice outlived the fall of Roman civilisation, and under the direction of the monks of the Middle Ages was carried on with success. It is supposed by some authors to have been introduced by the Moors into Spain, and from thence to have been re-introduced into other parts of Southern Europe; but more probably it lingered in England, as well as in parts of France, Spain, and Italy, from the time of the Romans, and as civilisation progressed, and greater attention was devoted to the arts of agriculture, its extension would be secured.

In Italy irrigation is carried out on a truly grand scale. The waters of the Po, the Adige, the Tagliamento, and all the minor streams are employed for this purpose, and there is no country which possesses a greater extent of rich water-meadow than Lombardy. The entire country, from Venice to Turin, has been spoken of as one great water-meadow, and yet irrigation is not there confined to grass lands, but is used in the cultivation of rice, vines, and other crops.

Public attention was first called to the importance of irrigation in this country by Robert Vaughan, who published a work in 1610, entitled so lengthily, that we only give the first few words:—"Most Improved and Long-experienced Water-works: containing the Manner of Summer and Winter Drowning of Meadow and Pasture," etc. Among the earliest established water-meadows are those of Wiltshire and Hampshire, which were made between 1700 and 1710. These meadows were not, however, laid out upon the best principle, and subsequently underwent considerable improvement. In the latter part of last century the subject of irrigation was again taken up in a treatise by George Boswell, published in 1780, and a series of papers followed by the Rev. T. Wright, of Auld, in Northants, published from 1789 to 1810. Instances are also on record in which irrigation was used in the cultivation of corn as well as grass in two parishes of Forfarshire and Aberdeenshire; but until very recently it was almost exclusively applied to grass in England, and the history of irrigation in Scotland dates from even a later time. In 1794-5 the Highland and Agricultural Society brought a practical irrigator from Gloucestershire, and several extensive proprietors set an example by forming irrigated meadows.

The subject of irrigation is extensive, and when we remember its various phases, and the numerous questions connected with the soils and situations where it may be employed, the waters most suitable for the purpose, the grasses and other plants which it benefits most, and the general management of water-meadows and irrigation works, it will be seen that there is material for volumes. Add to this the important aspect of irrigation as connected with the utilisation of the sewage of our towns, and some idea will be obtained both of the importance and extent of the subject. In these pages we propose to touch briefly upon all the above points; but especially upon the last, namely, the utilisation of sewage.

With reference to the various kinds of irrigation, the water may be applied either upon the surface, or from beneath. Superficial irrigation may be natural, as in the proximity of rivers which periodically overflow their banks; or artificial, by which is meant the conveying of water by channels so arranged as to distribute water evenly over the surface of land. The methods of doing this are controlled by the contour of the ground. In most cases the land is formed into beds or broad ridges, raised in the centre. The water is brought by a main "carriage," or ditch, and is allowed to flow into shallow trenches along the tops of the ridges. These trenches being full, overflow, and the water trickles down the sides of the ridges, finding its way into gutters provided for the purpose between the elevated "panes" or "stetches." The meadow is so laid out that while the carriage gutters on the tops of the ridges bring the water on to the meadow, the gutters in the hollows between the ridges serve to carry it off into the brook at a lower level. The accompanying figure will render this arrangement plain.



PLAN OF WATER MEADOW.

SECTION OF WATER MEADOW.

A, dam across river; B, main carrier; c, watering gutters; d, draining gutters; E, main draining gutter.

Where the land has a uniform slope the "catch-water" system of irrigation may be followed. In catch-water meadows the water is allowed to flow on to the most elevated portion of the ground by means of a "feeder," and as it overflows, and seeks a lower level, it is again collected by a second feeder, which crosses the line of greatest declivity, and re-distributes it over a still lower tract. Thus the water finds its way across a succession of feeders, each of which is a new point from which it is distributed. In either of these two methods "stops" are used in order to control the flow of the water, these stops being composed of boards placed across the feeders, or of sods placed so as to block the passages, and cause the water to overflow at the particular point required. Water-meadows may be formed wherever there is a constant supply of water, in dry as well as moist seasons, where the water is not required for mills or other purposes, and where the water "rights" are clearly defined so as to allow of the appropriation of the stream for the purpose of irrigation.

The clearer the water, the better for the purpose, and this at once marks a distinct difference between "warping" and irrigation. The former operation is in use in the extreme south-east of Yorkshire and north-east of Lincolnshire, in the proximity of the Humber. This and other rivers carry down vast quantities of mud from the interior of the country to the sea, the result being a deposition of alluvial material at their joint estuary. So considerable is this accumulation, that a long tongue of newly-formed land prolongs the south-east extremity of Yorkshire far into the ocean, and a lighthouse has been removed nearer to the sea three times within a very short historic period. This then is a case of natural warping, and by directing the flow of mud-charged waters on to lands adjacent to the river, the deposition is regulated according to the requirements of man. The rise and fall of tides assist in this operation, enabling successive floods of water to be poured over the portion of land embanked for warping. Thus, in a year, from one to three feet of soil of superior quality is accumulated.

In irrigation, the presence of mud or other *suspended* matter in the water is not desirable, since the deposition of fine particles on the leaves of growing plants would interfere with their functions and retard their growth; while substances in a state of *solution* are absorbed by the soil and the roots of plants, and minister to their wants. In an earlier paper we contrasted the two operations of drainage and irrigation, and at this point it may be well once more to point out the true functions of water when used for the latter purpose. Stagnant water, the enemy against which the drainer strives, is a "dog in the manger," uselessly occupying the interstices of the earth, keeping out the air, and, by its evaporation, rendering the land cold. In irrigation, on the other hand, it is essential that the field should be in the first place cleared of stagnant water, either by natural or artificial means. It must be dry, or drained. Next, from time to time a sheet or layer of moving water is allowed to find its way over its surface, carrying with it nourishment for plants, in many cases a higher temperature, and dissolving and rendering available the mineral wealth of the soil. Such, in few words, is the theory of irrigation.

Let us now glance very briefly at the general management of such meadows. The water is allowed to flow over the surface in winter and in summer, and provision is made for this by a proper arrangement of sluices. According to Mr. George Stephenson, the meadow should be periodically watered from October to January. Each watering is continued for fifteen to twenty days without intermission, and at the expiration of each of these periods the ground should be made completely dry for five or six days, *to give it air*. Mr. Bravinder, of Cirencester, who has the most intimate knowledge of the working of these meadows, says they "produce (after the winter's watering) an early and abundant supply of grass for ewes and lambs, and other stock, which is exceedingly useful in the spring. The custom is to consume the first crop by keeping sheep on the land till May, when other grass and green crops are ready to take the stock. The water is then turned on again, and subsequently a second crop is produced, and mown for hay about the latter end of June or beginning of July. The water is turned on a third time, and the aftermath which succeeds is fed off, which generally lasts till Christmas."

In all this, great care is requisite in keeping the water-courses clear, and regulating the "stops," so as to cause the water to flow evenly over the entire surface. Again, in severe frosts the watering must be discontinued, as by persisting in allowing water to flow at such times the temperature of the ground will be injuriously lowered. Usually, in districts where water-meadows obtain, a considerable extent of them is committed to the care of an experienced man, who both keeps the channels in good order and regulates the supply of water.

In conclusion we must briefly notice one of the most bold attempts at irrigation, under difficulties, ever attempted in this country. Mr. Campbell, of Buscat Park, Gloucestershire, conceived the idea of pumping water from the Thames (which skirts his property) to the highest point of his estate, and allowing it to fall from thence by gravity, and fertilise a large area of land. In order to carry out this scheme, a "plant" of no ordinary kind was required. A gigantic undershot wheel was placed across the Thames, which is not a very formidable river at that point; three powerful pumps, worked by the said wheel, were erected for the purpose of sending a constant stream of water by large iron piping up to a reservoir, or artificial lake, twenty-five acres in extent and sixty feet deep, scooped in the Oxford clay. Descending from this huge reservoir are delivery-pipes, carrying the fertilising fluid to those parts of the estate where it is required, and where it is further distributed over the surface. Some hundreds of acres have thus been irrigated, and splendid crops of Italian rye-grass have been the result, giving food to an immense number of sheep. Such is a very general sketch of the system of irrigation proposed, and, to a great extent, now in operation at Buscat Park. It is a grand idea, carried out with immense energy and great expenditure of capital. Whether suitable to the climate of this country, or likely to be remunerative, are questions which time alone can answer. In the case now under consideration the results obtained have been satisfactory, as exhibited in the production of heavy crops of Italian rye-grass, which would not have been nearly as good had it not been for the fertilising properties of the water which was thus boldly diverted from its original course, and turned over the land. It still remains, however, to be seen if the increased crops thus obtained will afford a sufficient return for the great outlay necessary in the first instance.

PRINCIPLES OF DESIGN.—XII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

DECORATIVE DESIGN.

Before we pass from a consideration of furniture and cabinet work generally, we must notice a few points to which we have as yet merely referred, or which we have left altogether unnoticed. Thus we have to consider upholstery as applied to works of furniture, the materials employed as coverings for seats, and the nature of picture-frames and curtain poles; we must also notice certain general errors in furniture, strictly so called. When examining certain wardrobes and cabinets in the International Exhibition of 1862, I was forcibly impressed with the structural truth of one or two of these works. One especially commended itself to me as of a fine structural character, while of classic formation. Just as I was expressing my admiration, the exhibitor threw open the doors of his well-formed wardrobe to show me its internal fittings, when, fancy my feelings at beholding the first door bearing with it, as it opened, the two pilasters that I conceived to be the supports of the somewhat heavy cornice above, and the other door bearing away the third support, and thus leaving the superincumbent mass resting on the thin sides of the structure only, while they appeared altogether unable to perform the duty imposed upon them. "Horrible! horrible!" was all I could exclaim.

Some of the most costly works of furniture shown by the French in the last Paris International Exhibition were not free from this defect; and this is strange, for to the rightly constituted mind this one defect is of such a grave character as to neutralise whatever pleasure might otherwise be derived from contemplating the work. We see a man, a genius perhaps—a man having qualities that all must admire; but he has one great vice—one sin which easily besets him. While the man has excellent and estimable qualities, we yet avoid him, for we see not the excellences but the vice. It is so with such works of furniture as those of which we have been speaking, for their defects are such as impress us more powerfully than their excellences.

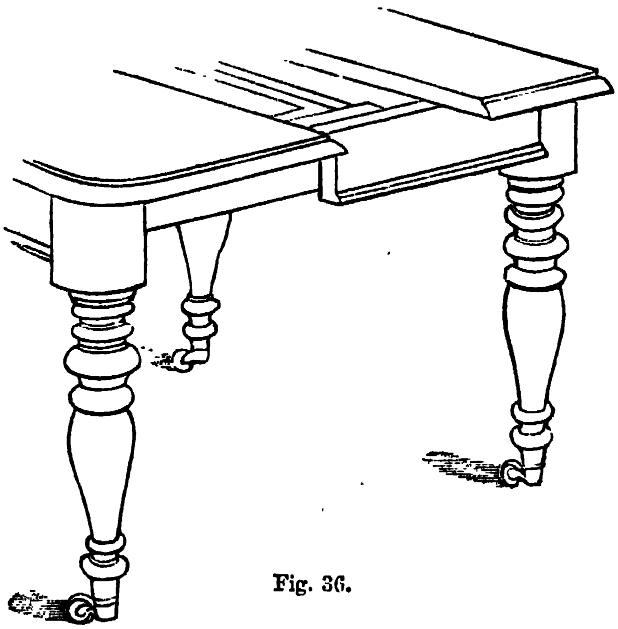


Fig. 36.

Respecting these works of furniture, this should be said: they are more or less imitative of works of a debased art period—of a period in which structural truth was utterly disregarded—yet this is no reason why we should copy the defects of our ancestors.

Infinitely worse than the works just spoken of, is falsely-constructed Gothic furniture, where the very truthfulness of structure is openly set before us. Not long since I was staying with a client whose house is of Gothic style. Being about to furnish drawings for the decorations of this mansion, I was carefully noting the character of the architecture and of the furniture, which latter had been designed and manufactured expressly for the house by a large Yorkshire firm of cabinet-makers. The structure of the furniture appeared just, the proportions tolerably good, the wood honest, and the inlays judicious: but, can it be imagined, the whole was a mere series of frauds and shams—the cross-grain ends of what should be supports were attached to the fronts of drawers, pillars came away, and such falsity became apparent as I never before saw. How any person could possibly produce such furniture, be he ever so degraded, I cannot think. I have seen works that are bad, I have seen falsities in art, but I never before saw such falsity of structure and such uncalled-for deception as these works presented. The untrue is always offensive; but when a special effort is made at causing a lie to appear as truth, a double sense of disappointment is experienced when the untruthfulness is discovered.

In his work on "Household Taste," to which we have before alluded, Mr. Eastlake objects, and I think very justly, to the character of an ordinary telescopic dining-table. He says: "Among the dining-room appointments, the table is an article of furniture which stands greatly in need of reform. It is generally made of planks of polished oak or mahogany, laid upon an insecure framework of the same material, and supported by four gouty legs, ornamented by the turner with mouldings which look like inverted cups and saucers piled upon an attic baluster. I call the framework insecure, because I am describing what is commonly called a 'telescope' table, or one which can be pulled out to twice its usual length, and, by the addition of extra leaves in its middle, accommodate twice the usual number of diners. Such a table cannot be soundly made in the same sense that ordinary furniture is sound; it must depend for its support on some contrivance which is not consistent with the material of which it is made. Few people would like to sit on a chair the legs of which slid in and out, and were fastened at the required height by a pin; there would be a sense of insecurity in the motion eminently unpleasant. You might put up with such an invention in camp, or on a sketching expedition, but to have it and use it under your own roof, instead of a strong and serviceable chair, would be absurd. Yet this is very much what we do in the case of the modern dining-room table. When it is extended it looks weak and untidy at the sides; when it is reduced to its shortest length the legs appear heavy and ill-proportioned. It is always liable to get out of order, and from the very nature of its construction must be an inartistic object. Why should such a table be made at all? A dining-room is a room to dine in. Whether there are few or many people seated for that purpose, the table might well be kept of an uniform length, and if space is an object it is always possible to use in its stead two small tables, each on four legs. These might be placed end to end when dinner parties are given, and one of them would suffice for family use. A table of this kind might be solidly and stoutly framed, so as to last for ages, and become, as all furniture ought to become, an heirloom in the family. When a man builds himself a house on freehold land, he does not intend that it shall only last his lifetime; he bequeaths it in sound condition to posterity. We ought to be ashamed of furniture which is continually being replaced; at all events, we cannot possibly take any interest in such furniture. In former days, when the principles of good joinery were really understood, the legs of such a large table as that of the dining-room would have been made of a very different form from the lumpy, pear-shaped things of modern use."

In nearly all these remarks I agree with Mr. Eastlake, and especially in his remark that, owing to the very nature of its construction, a modern dining-table must be an inartistic object. No work can be satisfactory in which any portions of the true supporting structure or frame are drawn apart; and this occurs to a marked degree in this table, as is shown in Mr. Eastlake's illustration, which we here copy (Fig. 36).

Another falsity in furniture is veneering—a practice which should be wholly abandoned. Simple honesty is preferable to false show in all cases; truthfulness in utterance is always to be desired. It was customary at one time to veneer almost every work of furniture, and even to place the grain of the veneer in a manner totally at variance with the true structure of the framework which it covered. This was a method of making works, which might in their unfinished state be satisfactory, appear when finished as most unsatisfactory objects. Since this time much progress has been made in a knowledge of truthful structure and of truthful expression, yet this method of giving a false surface by means of veneer is not wholly abandoned as despicable and false.

A few months back I had occasion to visit a cabinet warehouse in Lancashire, and the owner called my attention to the fine grain of some old English oak, and remarked that certain pieces of furniture were of solid wood. Upon investigation, however, I discovered that while the furniture in question was made throughout of oak, the bulk of the structure was of common wainscoting, and the surface was veneered with English oak. I confess that I would much rather have had the furniture without its false exterior, and daily my love for fine grain in wood gets less. I think that this arises from the fact that strong grain in wood takes from the unity of the work into which it is formed, and tends to break it up into parts, by rendering every member conspicuous. What is wanted in a work of furniture, before all other considerations, is a fine general form—a harmony of all parts—so that no one member usurp a primary place—and this it is almost impossible to achieve if a wood is employed having a strongly-marked grain.

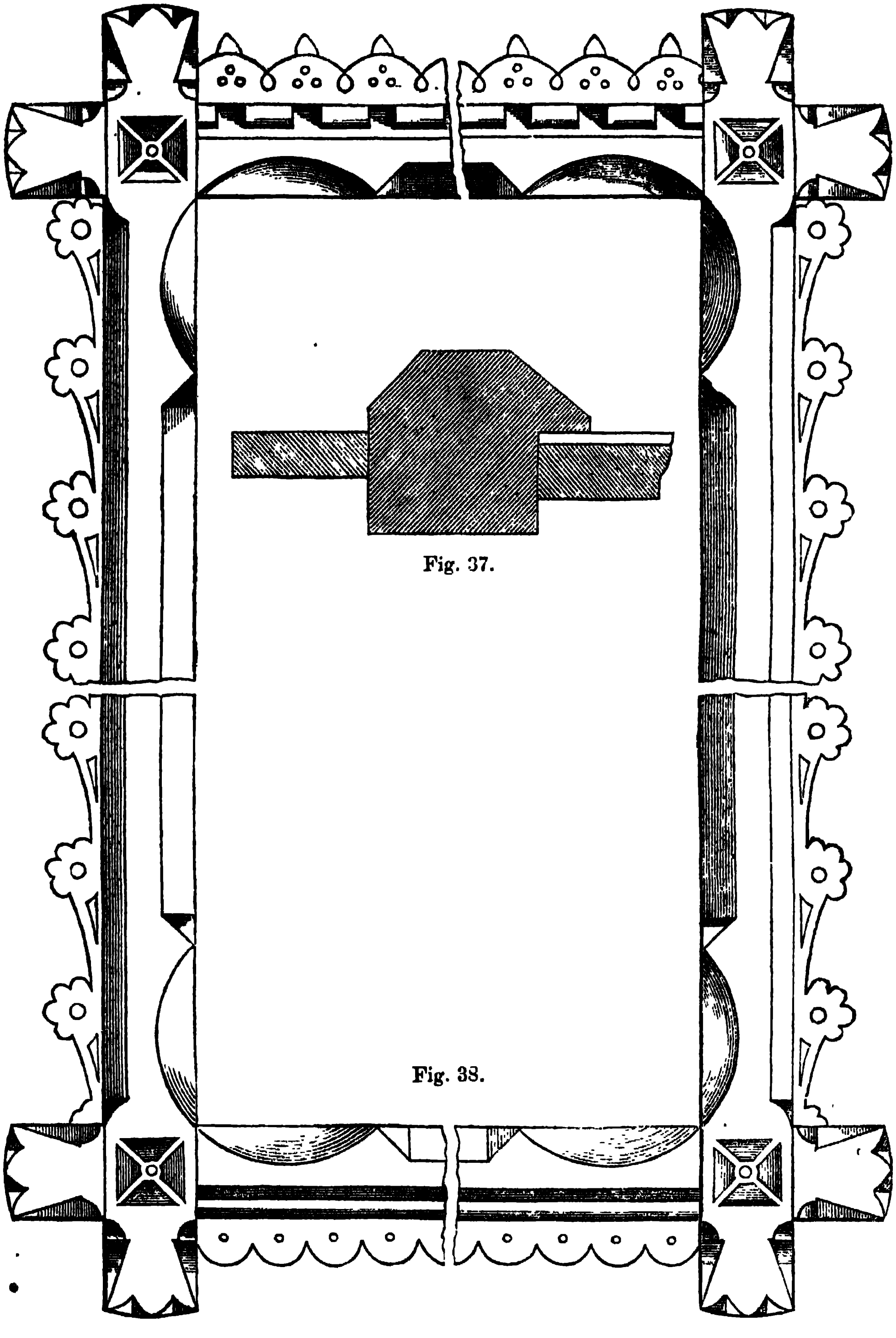


Fig. 37.

Fig. 38.

With us a room is considered as almost unfurnished if the windows are not hung with some kind of drapery. The original object of this drapery was that of keeping out a draught of air, which found its way through the imperfectly fitting windows; and the antitype of our window-hangings was a simple curtain, formed of a material suitable to achieve the purpose sought. Such a curtain was legitimate and desirable, and would contrast strangely with the elaborate festooning and quadrupled curtains of our present windows. We daily see yards of valuable material, arranged in massive and absurd folds, shutting out that light which is necessary to our health and well-being; and a pair of heavy stuff curtains and a pair of lace curtains to each window, each curtain consisting of sufficient material to more than cover the window of itself. An excess of drapery is always vulgar, and a little drapery usefully and judiciously employed is pleasant.

Many windows that are well made, and thus keep out all currents of air, need no curtains. If the window mouldings are of an architectural character, and are coloured much darker than the wall, so as to become an obvious frame to the window, and thus do for the window what a picture-frame does for a picture, no curtains will be required. I have recently had a wonderfully striking illustration of this. Two adjoining rooms are alike in their architecture: one is decorated, and has the window casement of such colours as strongly contrast, while they are yet harmonious, with the wall. Before the room was decorated, and the windows were thus treated, a general light colour prevailed, both on the wood-work and on the walls of the room, and curtains were hung at the windows in the usual way. With the altered decorations, the windows became so effective that I at once saw the undesirability of re-hanging the curtains, and yet not one of all my friends has observed that there are no curtains to the windows; while if the curtains are removed from the adjoining room, where the window-frames are as light as the walls, the first question asked is, "Where are your curtains?"

Curtains should be hung on a simple and obvious pole. All means of hiding this pole are foolish and useless. This pole need not be very thick, and is better formed of wood than of metal, for then the rings to which the curtains are attached pass along almost noiselessly. The ends of the pole may be of metal, but I prefer simple balls of wood. The pole may be grooved, and any little enrichments may be introduced into these grooves, providing the carving does not come to the surface, and thus touch the rings, which by their motion would injure it. Whatever is used in the way of enrichment should be of a simple character, for the height at which the curtain pole is placed would render very fine work altogether ineffective.

As to upholstery, I would say, never indulge in an excess. A wood frame should appear in every work of furniture, as in the examples we have given. Sofas are now made as though they were feather beds; they are so soft that you sink into them, and become uncomfortably warm by merely resting upon them, and their gouty forms are relieved only by a few inches of wood, which appear as legs. Stuffing should be employed only as a means of rendering a properly constructed seat comfortably soft. If it goes beyond this it is vulgar and objectionable. Spring stuffing is not to be altogether commended; a good old-fashioned hair seat is more desirable, as it will endure when springs have perished. As to the materials with which seats may be covered I can say little, for they are many. Hair cloth, although very desirable, is altogether inartistic in its effect. Nothing is better than leather for dining-room chairs; Utrecht velvet, either plain or embossed, looks well on library chairs; silk and satin damasks, rep, and many other fabrics are appropriate to drawing-room furniture, and upholsterers will find a new three-coloured material, called "The Windsor Brocade," just brought out by Messrs. Warde, of Halifax, useful for such purposes. Chintz I am not fond of as a chair covering, and in a bath-room I would rather have chairs with plain wooden seats than with cushions covered with this glazed material.

With a mere remark upon picture-frames I have done. Picture-frames are generally elaborately carved mouldings, or are simple mouldings covered with putty ornaments, which, whether carved or formed of putty, are overlaid with gold leaf; they are, indeed, highly ornamented gilt mouldings. I much prefer a well-formed, yet somewhat simple, black, polished moulding on the interior of which runs a gold bead. For prints and water-colours the annexed frame (Fig. 37) is all that can be desired. A fanciful yet good picture-frame was figured in the *Building News* of September 7th, 1866, which we now repeat (Fig. 38).

VEGETABLE COMMERCIAL PRODUCTS.

XVI.

VALUABLE BUILDING AND FURNITURE WOODS (*continued*).

EAST INDIAN EBONY (*Dalbergia latifolia*, L.; natural order, *Leguminosæ*).—The real raven-black ebony, one of the heaviest and hardest of all woods, and which in the fineness of its texture resembles ivory, is derived from this tree, which is indigenous to the island of Ceylon, and is also found in Java, Sumatra, and the Manilla Islands. This ebony is used for wind instruments and the keys of pianos.

The alburnum, or sap-wood of both the mahogany and ebony trees, is white and valueless, and is chipped off with the adze before the logs are shipped. The indurated heart-wood of these trees is the only part of the stem fit for industrial and economic purposes.

A great deal of ebony comes into commerce from the Cape of Good Hope, and arrives in England in sticks of about three to six feet long, and two to four inches thick.

BOXWOOD (*Buxus sempervirens*, L.; natural order, *Euphorbiaceæ*).—This is an evergreen shrub, a native of Southern and Western Europe. The wood is dense, compact, and admirably suited for wood engravers and also for the formation of graduated scales and fine works of art. It is imported in pieces four feet long and ten inches in diameter from Smyrna, Constantinople, and the Greek Islands. The fine saw-dust of this wood is sold at Nuremberg and other places as pounce, which dries writing quickly. The annual imports are between 3,000 and 4,000 tons.

SANDAL WOOD (*Santalum album*, L.; natural order, *Santalaceæ*).—This tree, which produces the beautifully perfumed sandal-wood, is a native of India and China. Sandal-wood is much used for entomological cabinets, as its fragrance is a preservative from insects. In China it is employed as incense, and is manufactured into toys. The shavings and saw-dust of sandal-wood are valuable in perfumery.

LIGNUM VITÆ (*Guiacum officinale*, Plum.; natural order, *Zygophyllaceæ*).—This is the hardest and heaviest wood known. It is of a dark olive colour, and cross-grained, the fibres running obliquely into one another, in a form somewhat resembling the letter X, so that it cannot be split with an axe, and is therefore divided by the saw. The tree is forty feet high, and four or five feet in circumference, with numerous knotted, much divided branches, abruptly pinnate leaves, and bright blue flowers. It grows in tropical America, especially in Jamaica, where it is very abundant, and whence our supplies are chiefly obtained. The timber of this tree is very valuable, where strength and durability are needed and weight is no object. Lignum vitæ comes over in billets about three feet in length and a foot in diameter, and is chiefly used for ship-blocks and pulleys. It takes a fine polish, and turns well, and for this reason is used by turners for articles requiring a hard close-grained wood.

BIRD'S-EYE MAPLE (*Acer saccharinum*, L.; natural order, *Aceraceæ*).—This tree is a native of North America, where it grows from Canada to Georgia. In early spring it yields, when tapped, an immense quantity of sugar. The beautiful wood known as bird's-eye maple, so much admired in cabinet work, is obtained from this species.

AMERICAN CEDAR (*Cedrela odorata*, L.; natural order, *Cedrelaceæ*), a native of the West Indies and Central America. This tree furnishes the wood used for the boxes in which cigars are packed, and for the inside portions of furniture.

PENCIL CEDAR (*Juniperus Bermudiana*; natural order, *Coniferæ*).—A North American tree, which furnishes the red wood for lead pencils.

LANCE-WOOD (*Duguetia Quitarensis*, St. Hilary; natural order, *Anonaceæ*).—This tree furnishes lance-wood, which is used by coachmakers for the shafts of gigs and other vehicles where both strength and elasticity are required. We receive lance-wood from Cuba and Guiana, whence it comes in the form of poles, fifteen to twenty feet in length and six to seven inches in diameter.

ROSEWOOD (*Triptolemœa* and *Dalbergia*; natural order, *Leguminosæ*).—Several undetermined species of these genera of trees furnish rosewood. We receive this wood from Brazil, in planks about twelve feet in length, flat on one side and rounded on the other, each being evidently one-half of the stem, with the bark removed. Violet-wood and king-wood, which come to this country also from the Brazilian forests, are probably only other species of the same plant, as both resemble the rosewoods. They are in much smaller pieces, usually in round sticks four or five feet long and from two to six inches in diameter. The best rosewood comes from Rio de Janeiro, and has recently been ascertained to be chiefly the timber of *Dalbergia nigra*. Rosewood is much used for library and drawing-room furniture, and is so named because, when fresh, it has the odour of a rose. The imports into England in 1863 were 2,120 tons.

BLACK WALNUT (*Juglans nigra*, L.; natural order, *Juglandaceæ*).—This is a large tree, indigenous to North America. Previous to the introduction of mahogany and rosewood, walnut was held in high estimation in the manufacture of costly furniture. It is still imported for furniture, although to a less extent than formerly, and is now chiefly employed in the manufacture of the stocks of all kinds of fire-arms.

SNAKEWOOD (*Piratinera Guianensis*; natural order, *Artocarpaceæ*).—This is a very beautiful ornamental wood; of a rich chestnut-brown colour, mottled with cloudy amber-coloured spots, resembling the markings of serpents—a scarce wood, imported from South America in sticks, two or three inches in diameter, and five or six inches in length. When dry, snakewood readily takes fire if rubbed against wood harder than itself, and is so used for obtaining fire by the native Indians.

SATIN WOOD (*Swietenia chloroxylon*, L.; natural order, *Cedrelaceæ*).—This is a handsome, hard, yellow veneering wood, occasionally imported from India, the West Indies, and South America, in logs seven or eight inches square and ten feet in length. It is used by cabinet-makers and upholsterers in inlaying work, and for picture-frames.

The far greater proportion of our building timber consists of the wood of various coniferous trees, which we import from America, Northern Europe, and Switzerland. The deal used in carpentry is the wood of several species of pine and fir. Thus, white deal is furnished by the Norway spruce fir (*Abies excelsa*, L.), and yellow deal by the Scotch fir (*Pinus sylvestris*, L.); the silver fir (*Abies picea*, Link.) furnishes a whitish deal used for flooring. There are numerous others, as the American and European larches (*Larix Americana*, Michx., and *L. Europæa*, L.), and the hemlock spruce fir (*Abies Canadensis*, Michx.), which are employed for ship and house building. We can only mention them, and we must now leave this branch of our subject, as we have not space for further selection. The names only of the trees—European, Asiatic, African, American, and Australian—which yield valuable furniture and building materials would form quite an extensive catalogue.

V. PLANTS PRODUCING VALUABLE GUMS, RESINS, AND BALSAMS.

The substances now to be considered are distinguished as follows:—

Resins are the inspissated or thickened juices of plants, and are commonly associated with an essential oil; they are insoluble in water, but are dissolved by alcohol and essential oils.

Gum Resins or *Balsams* are partly soluble in water, from the quantity of gum they contain.

Gums are soluble in water, but not in alcohol.

BALSAM FIR (*Abies balsamifera*, Michx.; natural order, *Coniferæ*).—This tree furnishes the Canada balsam so much used in mounting microscopic preparations of objects of natural history, as it not only preserves, but at the same time gives them transparency. This oleo-resinous fluid is contained in blisters of the bark, which are punctured, and the balsam is then caught as it exudes. It is imported from America.

INDIA-RUBBER, GUM-ELASTIC, or CAOUTCHOUC, is the hardened milky juice of many euphorbiaceous plants and others. That from the Brazils is the produce of *Siphonia elastica* (Rich.), a noble tree, growing to a height of sixty feet, with a light, stone-coloured bark. That collected in Central America, and now an important article of export all along the Atlantic seaboard, is obtained from *Castilloa elastica*. The Brazilian method of obtaining the caoutchouc, or india-rubber, is to spread the milky juice upon clay moulds, and dry it in the sun or in the smoke of a fire, which blackens it. The moulds are in the form of balls, bottles, and shoes. The juice is collected from incisions made in the stem, and is received into a cup of clay placed under the wound. It flows freely, to the extent of about four ounces daily from each tree. This juice is then smeared over the clay moulds in successive layers, which are dried separately, until a sufficient number have accumulated to give a proper thickness; the clay is then washed out, and the india-rubber is ready for the market.

In Central America the juice is collected from incisions made in the stem, and is received into vessels. A tree four feet in diameter will yield twenty gallons of juice, each gallon producing two pounds of good dried rubber; and an industrious man will collect twenty-five gallons a day. The milky juice is strained through a wire sieve, so as to exclude all impurities before it is transferred to barrels, in which the real manufacture of the rubber is performed. The best manner of converting the milk into rubber is by mixing with it the juice of a certain vine, termed by the natives *achuca*, which has the singular property of producing coagulation within the space of five minutes. About a pint of the infusion of the vine is well mixed with every gallon of the milk. This is done in a large tin pan, and the rubber separates as a soft mass from the brown liquid. This mass is then placed on a board, slightly pressed by hand, and rolled out with a piece of heavy wood. A great quantity of water is thus squeezed out, and the rubber, which has now assumed its elasticity, is made into flat round cakes a quarter of an inch thick, twenty inches in diameter, and perfectly white in colour. Hitherto the greater portion of the caoutchouc imported has been received from South America, but latterly a considerable amount has come from Singapore, Assam, and other places in the East Indies. This is the product of the *Ficus elastica*, L. (natural order, *Urticaceæ*), or the famed banyan tree, so celebrated for its pillared supports, "whose daughters grow about the mother tree," and which has furnished the motto "*Tot rami quot arbores*" to the Royal Asiatic Society. But this product is nevertheless very inferior to that furnished by the Brazilian india-rubber tree.

Caoutchouc is contained in the juices of many tropical trees, and in small quantities in many plants of temperate regions; it seems to form an essential part of the milky juices which are characteristic of the *Euphorbiaceæ*, *Apocynaceæ*, and *Urticaceæ*.

In 1864, 71,027 cwt. of caoutchouc were imported into the United Kingdom in the raw state—viz., from South America, 52,097 cwt., valued at £389,576; and from the East Indies, 11,930 cwt., valued at £113,069. The same year, our exports of caoutchouc to Europe and the United States were 29,107 cwt., valued at £205,932. The total import for 1867 was 79,756 cwt.

GUTTA-PERCHA (*Isonandra gutta*, Hook.; natural order, *Euphorbiaceæ*).—This is a magnificent tree, sixty or seventy feet in height and from five to six feet in diameter, growing in the Malayan Archipelago. Gutta-percha is the inspissated juice of this tree, and is procured as follows:—The trees are felled, the bark removed, and the milky juice which is found between the bark and wood is collected and poured into a trough made from the stalk of the plantain-leaf. It quickly coagulates on exposure to the air, and is then kneaded into cakes for exportation. Gutta-percha is one of the most valuable vegetable productions ever discovered. It is in its natural state hard, rough, dry, opaque, tough, inflammable, and slightly soluble. On immersion in hot water it becomes softened and capable of being moulded into any figure, which it retains when cold; a number of pieces, too, may be united so perfectly as to show no mark whatever of their junction. It is not elastic, but so tough that a thin slip, one-eighth of an inch in substance, will sustain a weight of forty-two pounds. A great variety of articles are made from gutta-percha, and, above all, cables for the conveyance of the submarine telegraph, which, without this invaluable substance, could not have existed.

The demand for gutta-percha is continually increasing, and it is certain that a process too destructive to the trees is adopted in the endeavour to furnish the requisite supply.

In 1864 the gutta-percha imported amounted to 36,750 cwt.; and, at the very lowest estimate, not fewer than 300,000 trees were destroyed to obtain that amount. A short time ago this tree was abundant on the island of Singapore; now few if any other than small plants are to be found there, all the large trees having been felled. The range of its growth appears, however, to be considerable, as it doubtless extends over all the islands of the Malayan Archipelago.

TAR (*Pinus sylvestris*, L.; natural order, *Coniferæ*).—Tar is an impure turpentine, viscid, and brown-black in colour, procured by destructive distillation from the roots of various coniferous trees, particularly the above species. This process was known to the ancients, being described by Theophrastus, and is nearly the same now as in his time.

A bank is chosen near a marsh or bog, as the roots of pines so situated always yield the greatest supplies of tar; in this bank a conical cavity is formed, the sides of which are beaten down and rendered as firm as possible with heavy wooden mallets. A cast-iron pan is placed at the bottom of the hole or funnel, with a spout which projects through the side of the bank, and barrels are placed beneath this spout to collect the tar as it comes away. This cavity is then filled with the roots of the pine, which are cut and neatly packed so as to fill up the entire space, and the whole is covered over with turf and beaten down with the mallet or stamper. The roots in the inside of the cavity are then set on fire, and the tar, as it distils, runs down the sides into the iron pan, passing through the spout into the barrels, which, as fast as filled, are bunged, and are then ready for exportation.

Tar is used chiefly by seamen, for preserving cordage and wood from the effects of the atmosphere. Nearly all our tar comes from Russia, Norway, and Sweden; the United States, also, supply us with a considerable amount; the forests between Bayonne and Bordeaux in France, the Black Forest, and the forest of Thuringia, in Germany, send large quantities into commerce. In 1851, 24,000 tons were received into this country.

Pitch is tar condensed or deprived of the more volatile parts by distillation. The tar is boiled in an open iron pot until all the volatile matters are driven off; the residuum remaining is pitch. This is a black, solid, and glossy substance, very brittle when cold, but softening and becoming ductile when heated. That used in this country is mostly home manufactured. Pitch is frequently mixed with tar, and used for similar purposes, in ship-building, for caulking the seams of vessels, etc.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VII.

THE CYCLOID (*continued*).

THE *involute*, *cycloid*, *epicycloid*, and *hypocycloid* curves are much used in drawing the exact curves forming the teeth of wheels working in racks or in gear with each other; and these will therefore be more fully worked out in the lessons on "Technical Drawing."

The cycloid was invented by Galileo, an eminent mathematician and natural philosopher. He was born at Pisa in 1564, and died in 1642.

To describe the cycloid.

Draw the director A B, (Fig. 63), the generating circle C, and a line through the centre, called the line of centres, D E, parallel to A B. Draw the diameter VI 6, and divide each half of the circle into any number of equal parts—viz., 1*a*, 2*a*, etc.

On each side of point VI, set off the lengths V*a*, IV*a*, III*a*, etc., and V*b*, IV*b*, III*b*, etc., equal in size and number to the divisions in the circle.

From O, I*a*, II*a*, III*a*, etc., erect perpendiculars, cutting the line D E in I, II, III, etc.

From each of those points describe circles equal to the generating circles. From V*a* set off on the circle of which V is the centre the length of the line VI 5*a*—viz., 5*b*. Mark off the same length on the corresponding circle, from V*b*. From IV*a* set off on the circle drawn from centre IV the length of the line VI 4*a*, and do the same on the corresponding circle from IV*b*.

Proceed thus, setting off the lengths of the lines VI 3, 2, and 1, on the circles resting on the points numbered correspondingly (in Roman figures), and through the points marked on the various circles—viz., 1*b*, 2*b*, 3*b*, etc.—draw the curve.

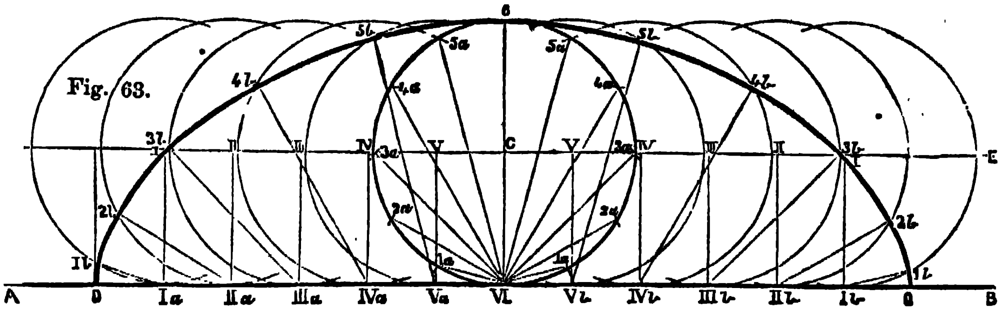


Fig. 63.

THE EPICYCLOID AND HYPOCYCLOID.

When a circle, instead of rolling along a straight line, rolls around the edge of another circle, any point in it will describe the curve known as the *epicycloid* (Fig. 64).

To describe the epicycloid.

Draw the directing circle B C, and the generating circle D.

From A, with radius A D, describe the circle of centres E F.

Divide the generating circle into any number of equal parts, 1*a*, 2*a*, etc., and set off these lengths from VI on the *directing* circle C B—viz., the points marked I, II, III, etc., in the larger Roman figures.

From A draw lines through I, II, III, etc., cutting the circle E F in i, ii, iii, etc. (smaller Roman figures).

From each of these points, as centres, describe circles similar to the generating circle.

From points v, iv, iii, ii, i, set off on the circles resting on them the lengths VI 5*a*, 4*a*, etc.; and through the points thus obtained — viz., 1*b*, 2*b*, 3*b*, etc. — the epicycloid is to be drawn.

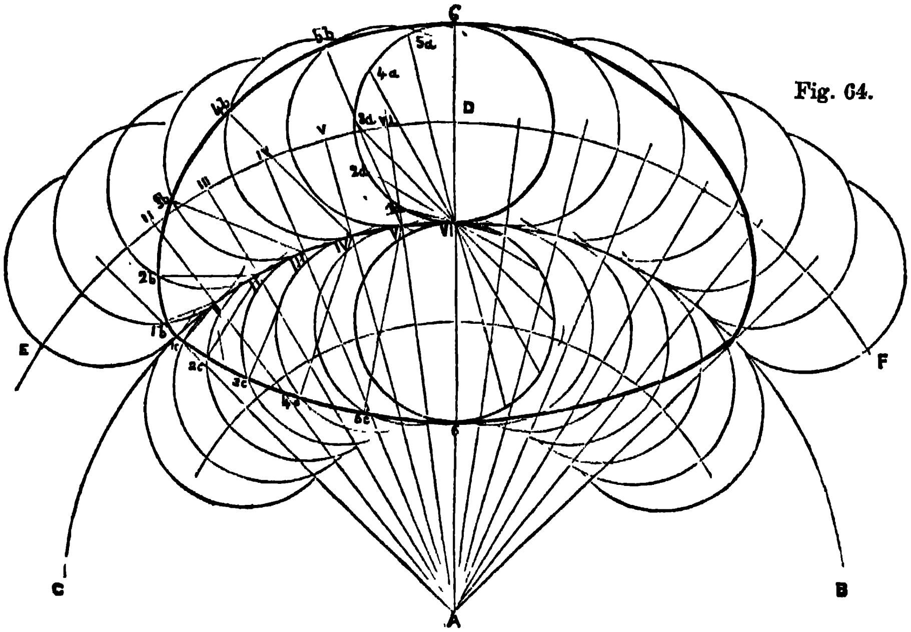


Fig. 64.

When the generating circle rolls *inside* instead of outside the directing circle, the curve traced is the *hypocycloid* (Fig. 64).

It is constructed in precisely the same manner as the *epicycloid*, excepting that the lengths VI 5*a*, etc., are set off from V, IV, III, etc., *inside* instead of outside the directing circle; and the points 5*c*, 4*c*, 3*c*, etc., are thus obtained.

If the *diameter* of the generating circle were equal to the *radius* of the directing circle—that is, if VI 6 extended to A—a

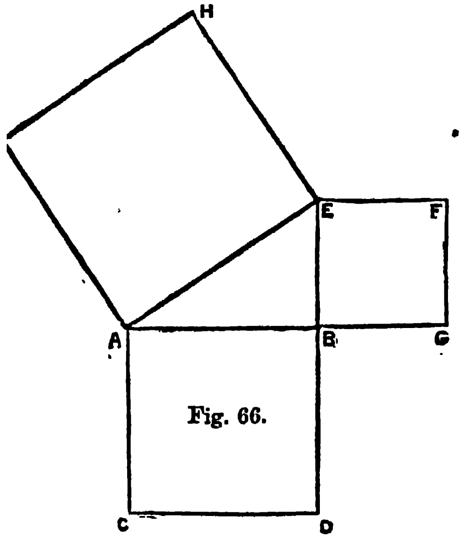


Fig. 66.

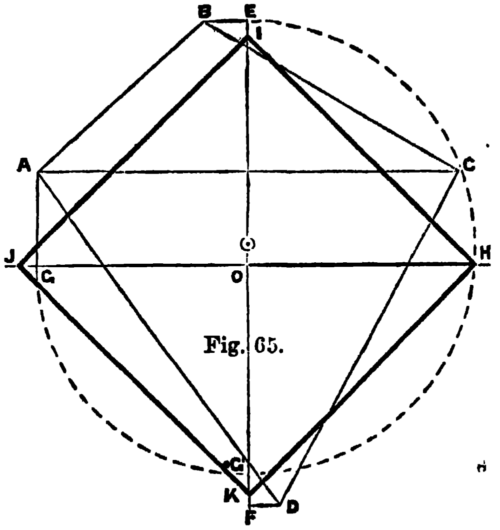


Fig. 65.

point in the generating circle, instead of generating a *curve*, would trace a *straight line*.

To construct a square equal in area to a given quadrilateral figure, A B C D (Fig. 65).

Draw the diagonal A C, and bisect it by a perpendicular.

From B and D draw lines parallel to A C, and cutting the perpendicular in E and F. Draw a line bisecting E F in O, and from A draw a line parallel to E F, and cutting this bisecting line in G. Find a mean proportional between O E and O G—viz., O H.

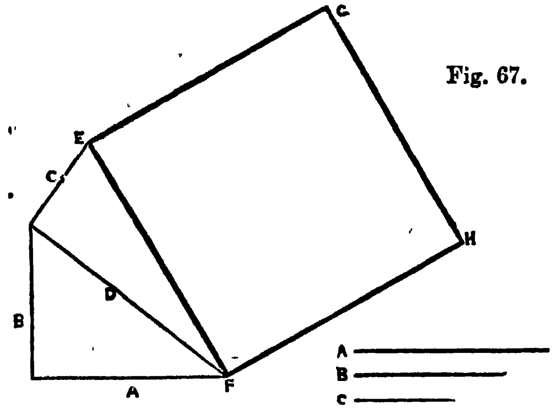


Fig. 67.

Set off the length O H (the semi-diagonal) from O on E F and O G—viz., I, J, K. Join H I J K, and the square will be equal to the quadrilateral figure A B C D.

To construct a square which shall be equal in area to two other squares added together (Fig. 66).

Place the two squares so that a side of the one, as A B, shall be at right angles to one side of the other, as B E. Draw the line A E.

Now, according to Euclid (I. 47),* "In any right-angled triangle, the square which is described upon the side subtending the right angle, is equal to the squares described upon the sides which contain the right angle." And it will be seen that A B E is a right-angled triangle, and that the squares A B C D and B E F G are described upon the sides of it which contain the right angle; and therefore the square A E H I, which is described on (the hypothenuse) A E, which subtends the right angle, is equal to the sum of the two other squares.

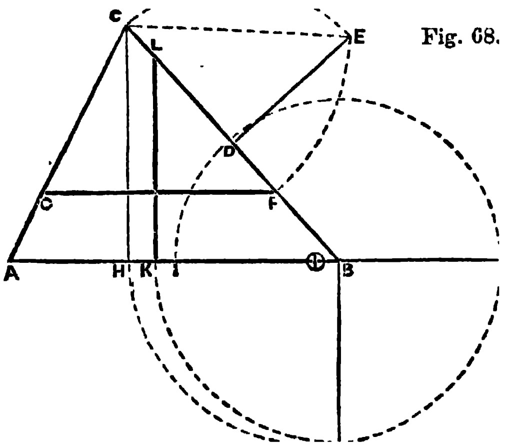


Fig. 68.

To construct a square equal in area to any number of squares added together (Fig. 67).

This is done by merely carrying on the process shown in the last figure. Let it be required to construct a square, which shall be equal to the areas of the three squares of which A, B, and C are the respective sides. Place B at right angles to A, then the hypothenuse D would be the side of the square equal in area to the squares constructed on A and B. Place C at right angles to D, draw E F, and construct a square upon it; then E F H G is equal to the squares constructed on C and D, and therefore equal to the squares constructed on all three lines. Any number of squares may be thus added together.

To divide a given triangle, A B C, *into two equal parts by a line parallel to one of its sides* (Fig. 68).

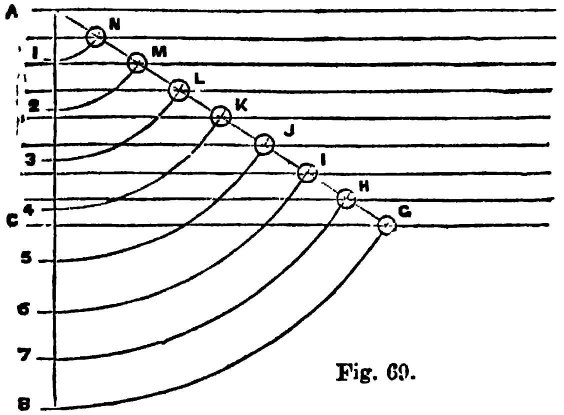


Fig. 69.

Bisect one of the sides, as C B, in the point D, and erect the perpendicular D E equal to D C. From C, with radius C E, describe an arc cutting C D in F. From F, draw F G parallel to A B, which will divide the triangle into two parts of equal area.

To divide a triangle into two equal parts by a line perpendicular to one side (Fig. 68).

From C, draw C H perpendicular to A B. Bisect A B in I.

Find a mean proportional between B H and B I—viz., B J.

From B, set off B K equal to B J, and the perpendicular K L will divide the triangle as required.

To divide the space contained between the lines A B *and* C D *into equal parts, by means of lines parallel to* A D (Fig. 69).

Draw the line E F perpendicular to A B, and set off on it equal lengths corresponding to the number of spaces into which A B C D is to be divided—viz., 1 to 8. These spaces may be *any* size, but must be *equal*. From E, with radius E 8, describe an arc cutting C D in G. Draw E G. From E, with radius E 8, E 7, E 6, etc., describe arcs cutting E G in H, I, J, K, L, M, N.

Draw lines parallel to A B through these points, and the space will be divided as required.

To draw a circle of a given radius, which shall touch another given circle and a straight line (Fig. 70).

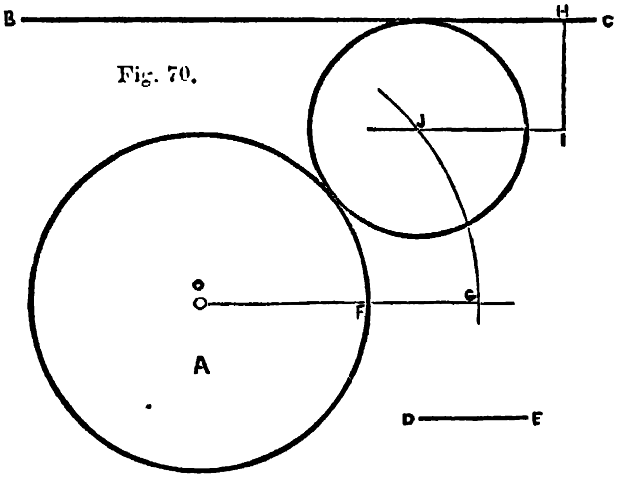


Fig. 70.

Let A be the given circle, B C the straight line, and D E the radius of the required circle. The question here is, to find a point which shall be the centre of a circle of a given radius, which shall touch the given circle and straight line. From O, the centre of the given circle, draw a radius and produce it. From the periphery of the circle, and on this radius, set off F G, equal to D E. From O, with radius O G, describe an arc. At any point, as H, in B C, draw a perpendicular, H I, equal to D E. From I draw a line parallel to B C, cutting the arc drawn from O in J. From J, with the required radius, describe a circle, which (if the work has been *accurately* done) will touch the given circle and straight line.

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* This proposition is said to have been discovered by Pythagoras, a disciple of Thales, who, after travelling in India and Egypt in pursuit of knowledge, settled in Tarentum, in Italy, where he founded the celebrated Pythagorean school, 550 years B.C.

PRACTICAL PERSPECTIVE.—VI.

FIG. 28 is a perspective view of a strong table or bench, the edge of the top of which is "flush" with the legs and surrounding rail.

Having drawn the picture line and horizontal line, and having fixed the centre of the picture and point of distance, place the point B (the nearest angle of the table) at the required distance on the left or right of the spectator.

From B set off B C′, equal to the complete length of the table, and from B and C′ draw lines to the centre of the picture.

On the other side of B set off B D, the width of the end of the table, and from D draw a line to the point of distance (not shown in this figure), cutting B C in D′.

From D′ draw a horizontal line, cutting C′ C in E. The figure C′ E D′ B will then be the perspective view of the area covered by the table. From B and C′ mark off on the picture line B G and C′ F equal to the thickness of the legs, and from G and F draw lines to the centre of the picture, cutting D′ E in G′ and F′.

Now on the other side mark off B H equal to B G, and from D set off the same width—viz., D J. From H and J draw lines to the point of distance, cutting B D′ in H′ and J′.

From H′ draw a horizontal line, cutting G G′ in G″, and cutting F F′ in I and C″. From J′ draw a horizontal line, cutting G G′ in K, and F F′ in L and M.

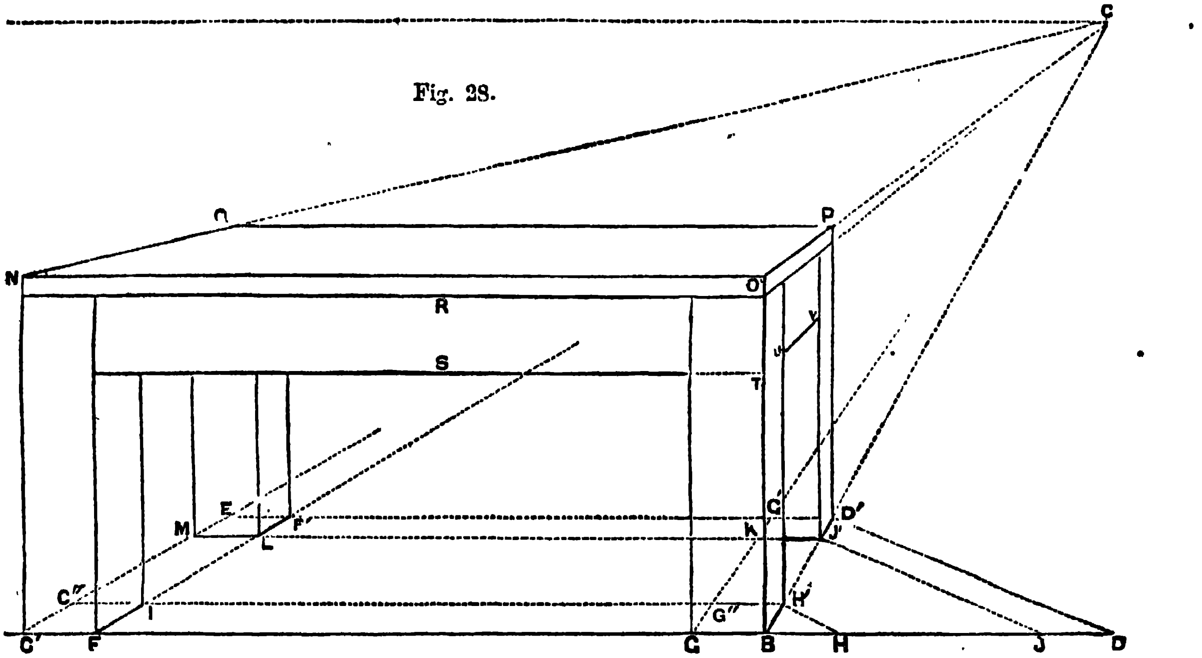


Fig. 28.

It will then be seen that at the corners of the original area the plans of the four feet are delineated—viz., C′ F I C″, G B H′ G″, M L F′ E, K J′ D′ G′, and a complete ground-plan of the table is thus put into perspective. Now proceed with projecting the table itself, in the following manner:—

At C′ and B erect perpendiculars, make these the required height of the surface of the table, and draw the horizontal N O.

From N and O draw lines to the centre of the picture.

Draw a perpendicular at D, meeting O C in P. Draw the horizontal P Q, which will complete the block of the table.

Draw the horizontal R for the lower edge of the plate of the table, and from the point where it meets the perpendicular B O draw a line to the centre.

Now draw the perpendiculars F, G, H′, and J′, and the horizontal S, between F and G, for the framing of the table.

This framing is mortised into the legs, and therefore the line must not be drawn across the lines F and G, which represent the edges of the legs; but as it is necessary to find the correct position of this framing on the perspective side, produce S lightly to the angle T, and from T draw a line to the centre of the picture. Strengthen this line only between the points U and V.

Strengthen that portion of the horizontal J′ K which lies between J and the perpendicular H′. It will be easy to understand that the inner edge of the distant leg of the table would rise from K, but in the present study this is hidden by the leg G B. The student is, however, recommended, when he has worked the present study, and understands the principles laid down, to change the position, for it will be evident that if the object were placed farther left, the point K would become visible. For the fourth leg, the upper part of which is hidden by the top of the table, draw perpendiculars from the points M, L, F, and these will complete the object. The whole of the lines constituting the figure should now be thickened or inked.

Fig. 29.—This study is merely another view of the last subject, in which the end B O P D is parallel to the picture-plane.

The working of this will be carried on in precisely the same manner as the last, with this exception, that in starting, the points B, H, J, D are marked on the picture-line, and lines drawn from them to the centre of the picture. Then the points G, F, C′ are marked, and lines drawn to the points of distance, all of which is the reverse of what was done in the last figure; and thus it will be seen that the figure B D C′ E represents the plan of the table with its narrow end towards the spectator, whilst the long side is seen receding from the plane of the picture.

The lines and points are lettered to correspond with those in the last view, so that the change of position may be clearly traced. It is not necessary to repeat the working.

EXERCISE 14.

Scale, ½ inch to the foot. Height of the spectator, 6 feet; distance, 18 feet.

Put into perspective a cross made of stone 1½ foot square—total length of the upright, 12 feet; length of the arm, 7½ feet. The arm crosses the upright at 7½ feet from the bottom of the upright. Draw a plain elevation of this cross, and then project a perspective view when lying on the ground, at 3 feet on the left of the spectator, in such a manner that the end of the arm is parallel to the picture-plane, and is in the immediate foreground.

EXERCISE 15.

Put into perspective the same cross when lying on the ground, so that the lower end of the upright is parallel to the picture-plane and 6 feet within the picture; all other measurements at pleasure. By this term—frequently used in examination papers—is meant that the student may fix his own dimensions, so long as he shows that he understands the working out of the principle.

EXERCISE 16.

Scale, height, and distance of spectator at pleasure.

There are two blocks of stone, 2 feet square at their base, and 8 feet high. They stand 4 feet apart, and across the top of them rests a block, 8 feet long and 2 feet square at its ends—the faces of all three blocks being in one plane, that is, if a flat surface were placed against them, every part of the faces of all three blocks would touch it.

Put into perspective this object, when the plane of its face is parallel to the picture-plane, and when it stands at 8 feet on the left of the spectator and 10 feet within the picture.

EXERCISE 17.

Put into perspective the same object when standing so that its face is at right angles to the picture-plane, at 9 feet on the right of the spectator, and 6 feet within the picture.

EXERCISE 18.

The height of the spectator is 6 feet, his distance 18 feet, the scale being 1 inch to the foot.

Put into perspective the table which forms the subject of Figs. 28 and 29 when standing at 4 feet on the right of the spectator and 6 feet within the picture—the long side of the object to be parallel to the picture-plane. The dimensions of the table may be at pleasure.

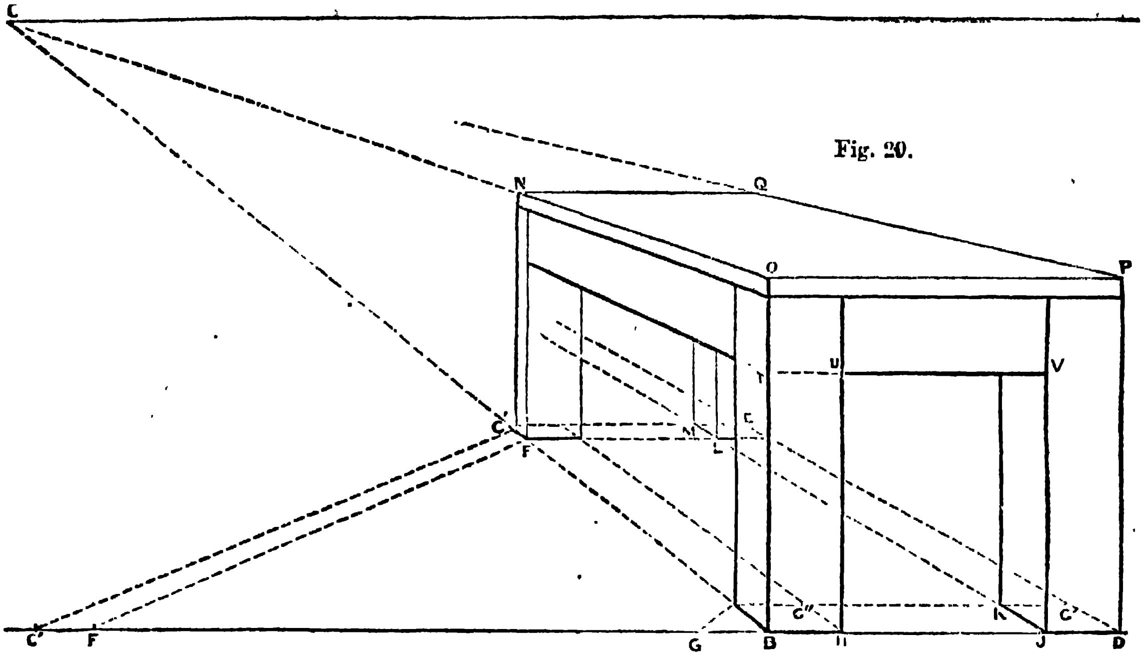


Fig. 29.

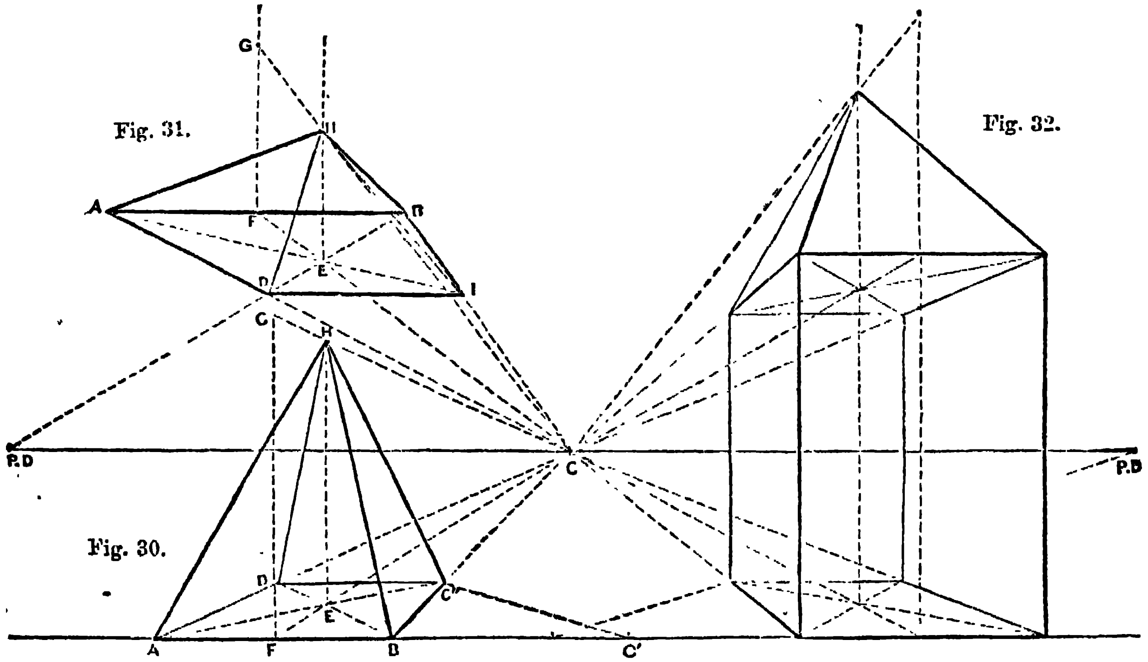


Fig. 31.
Fig. 32.
Fig. 30.

EXERCISE 19.

Put into perspective the same object when its end is parallel to the picture-plane—at 7 feet on the left of the spectator, and 5 feet within the picture.

The object of the next study is to teach the method of making perspective projections of pyramids.

Fig. 30.—Let the length of the side of the base be represented by A B; then, as has already been shown, the perspective view of the plan will be the figures A B C″ D.

Now if the diagonals A C″ and B D be drawn, intersecting in E, it will be clear that the apex of the pyramid will be *somewhere* on the perpendicular raised on E.

But this perpendicular lies within the picture, and therefore the *true* height of the pyramid will be somewhat diminished; therefore, draw a line from the centre of the picture, through E, and meeting the picture-line in F.

F is therefore E brought to the foreground, and a perpendicular raised in F will represent the perpendicular E when it has travelled in a track at right angles to the picture until it reaches the picture-line; and now these two lines are said to be in *one plane*, because if a wall extended from F to the centre of the picture, both these perpendiculars would be portions of the surface of such wall or plane; and thus a line drawn on the plane from any point in the perpendicular F, parallel to the base-line of the plane, would pass through the perpendicular E.

Now the plane supposed to stand on F C is at right angles to the picture; and therefore F is drawn to the centre of the picture, and a line drawn from any part of the perpendicular F parallel to the ground-line must also vanish in the centre of the picture.

Therefore, mark on the perpendicular F the real height of the pyramid—viz., F G. From G draw a line to the centre of the picture, cutting the perpendicular E in H, which is the perspective position of the apex. From A, B, C', and D draw lines to H, which will complete the figure.

Fig. 31 shows the perspective projection of a pyramid when higher than the level of the spectator. Here the length of the side of the base is A B, and from A and B lines are drawn to the centre of the picture. Then from B a line drawn to the point of distance gives D, the distant angle, and the horizontal D I completes the view from below of the base of the pyramid. In this there will thus already be one diagonal—viz., B D: draw the second, A I, intersecting B D in E, and at E erect a perpendicular. From the centre of the picture draw a line through E, meeting A B in F. At F draw a perpendicular, and on it mark the real altitude of the pyramid—viz., F G. From G draw a line to the centre of the picture, cutting the perpendicular E in H. Then H is the position of the apex. Draw lines from A, B, I, and D to H, which will complete the projection

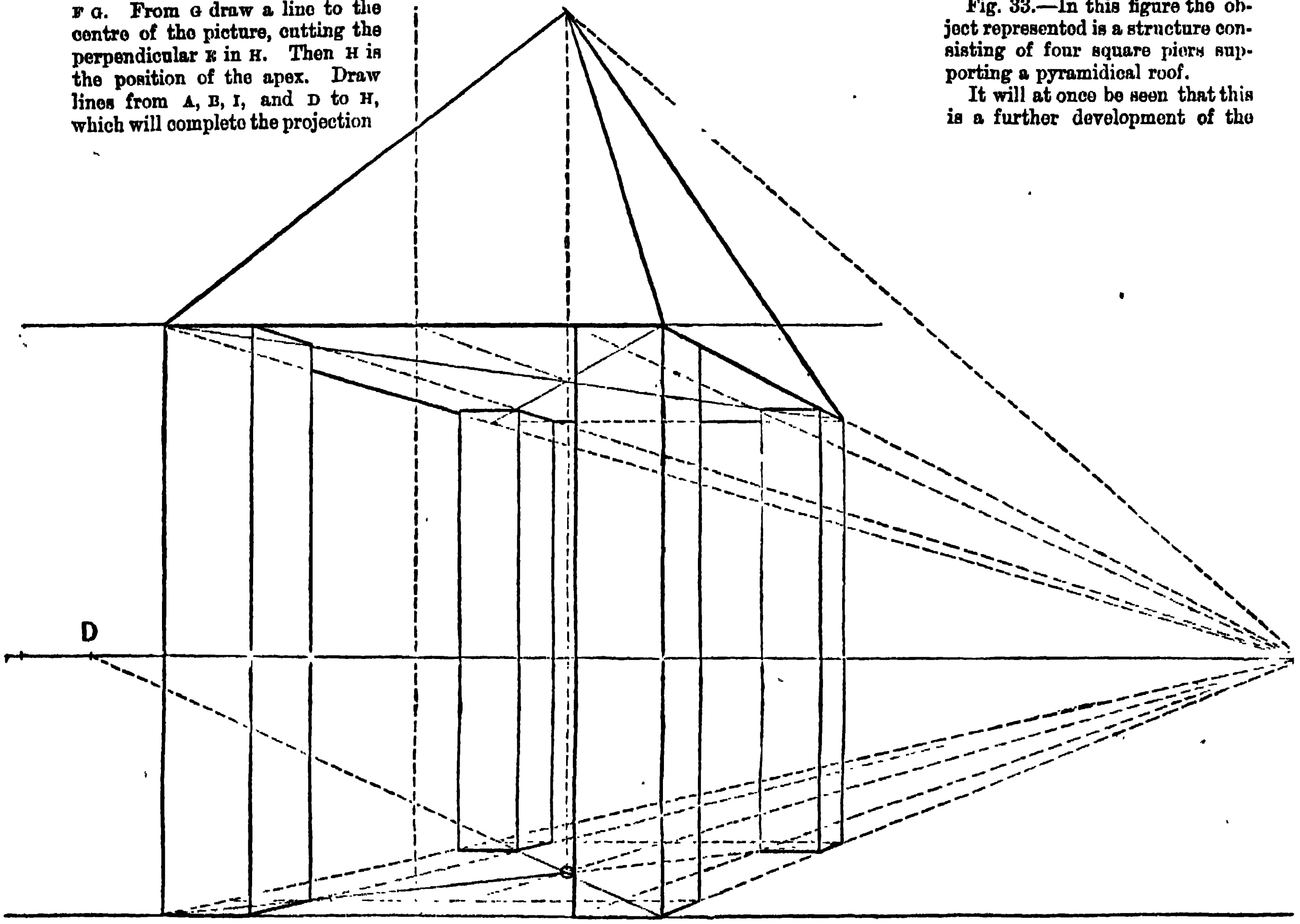
Fig. 32 will, it is believed, require scarcely any explanation. It represents merely a cubical figure placed on the right of the spectator, and on this rests a square pyramid.

Having drawn the block, and rendered it as if transparent, draw diagonals either in the upper surface of the base, or in the under surface of the top, and through the intersection of the diagonals in either the one, the other, or both, draw a perpendicular.

From the centre of the picture draw a line through the intersection of the diagonals, cutting the picture-line, or the upper edge of the cubical figure. On this point raise a perpendicular, and set off on it the real height of the pyramid above the block on which it stands.

From the point thus marked draw a line to the centre of the picture, which, cutting the perpendicular rising from the intersection of the diagonals, will give the perspective height of the pyramid.

Fig. 33.



Exercise 20.

The height of the spectator is 6 feet, and his distance 15 feet. Scale, ¼ inch to the foot.

Put into perspective a pyramid, the base of which is 6 feet square, and the altitude of which is 8 feet. The pyramid stands at 5 feet on the right of the spectator.

Exercise 21.

Put into perspective the same pyramid when standing at 4 feet on the right of the spectator, and at 8 feet within the picture.

Exercise 22.

The same picture and the same horizontal line, etc., to be used.

Put into perspective a block, 9 feet high, and 4 feet square at base, with a pyramid 5 feet high resting on it, its edges corresponding with those of the upper end of the block. The object is to stand 5 feet on the left of the spectator.

Fig. 33.—In this figure the object represented is a structure consisting of four square piers supporting a pyramidical roof.

It will at once be seen that this is a further development of the subject of the last study, the block being, as it were, hewn away, leaving only the piers standing at the angles.

The position, height, and distance of the spectator having been fixed, mark the position and width of the base, and put the whole ground-plan into perspective, as already shown in the study in Fig. 28. On this plan erect the piers; and the line carried round, uniting the outer edges of the tops of the piers, will form the base of the pyramid.

Draw diagonals in the base, and at their intersection erect a perpendicular. From the centre of the picture draw a line passing through the intersection of the diagonals, and meeting the edge of the base of the pyramid. At this point draw a perpendicular equal to the altitude of the pyramid, and from its extremity draw a line to the centre of the picture, cutting the distant perpendicular in a point, which will be the apex of the pyramid. To this point draw lines from the angles, and these will complete the projection.

MINING AND QUARRYING.—II.

By George Gladstone, F.C.S.

COAL.

IMPORTANCE OF COAL—ANNUAL CONSUMPTION—EXTENT OF SUPPLY—GEOGRAPHICAL DISTRIBUTION.

Coal is so essential in all mining and metallurgical processes, that it fitly takes the first place in the present series of articles. Fuel of one sort or another is of course to be found in every country under heaven; but fuel of a sufficient heating power, and at a comparatively reasonable price, is one of the most important elements in the prosperity of a nation.

Great Britain is singularly blest in this respect. The supplies are large. Some people may, perhaps, be disposed to think that this is not altogether an unmixed good; for (whether fortunately or not to succeeding generations) the extent of the supply, and the convenient situation of many of the coal-fields to ports of shipment, naturally encourage exportation on a large scale to foreign parts. Both the home consumption and the export have indeed increased of late years with such rapid strides, that alarmists have been raising the cry of the early exhaustion of our coal-fields.

This led to serious inquiry into the matter, and very different opinions were arrived at by those best qualified to judge. One geologist, writing in 1861, estimated the total available supply of the British coal-fields at 79,843,000,000 tons, which at the rate of consumption of 1859—viz., 72,000,000 tons—would make it last 1,100 years. But the writer did not shut his eyes to the fact that the annual consumption was increasing at a rapid ratio, and he accordingly allowed in his calculations for an annual increase of 1,500,000 tons. The effect of this allowance was to reduce the 1,100 down to only 325 years!

The increase of 1,500,000 per annum was based upon the statistics of the previous five years; but in 1867 the production was no less than 104,500,000 tons, representing an increase between 1859 and the latter date of no less than 4,500,000 tons per annum. In the face of such astounding facts as these, it seems almost futile to attempt an estimate of the probable duration of our coal-fields. One thing is certain, that every right-minded person must hail with gratitude every invention of modern science which tends to economise the consumption of fuel.

The elements that have to be considered in the calculation of the available supply are rather numerous. 1. The depth to which workings can be carried. 2. The thickness of workable coal in the various coal-fields. 3. Their area. 4. The extent to which they are already exhausted. 5. The probability of extending their area, or of opening up new fields.

1. In the previous paper it has been shown that in consequence of the natural increase of temperature a mine will be sufficiently hot (viz. 80°) at a depth of 1,750 feet. But in order to get an available supply of 79,000,000,000 tons, it is calculated that coal-mining will have to be carried to a depth of 4,000 feet. This, of course, would be impossible without artificial contrivances; but, however shallow a coal mine may be, the ventilation must be attended to for the purpose of carrying off the dangerous gases. The means of ventilation are therefore well understood by miners, and its effect in cooling the air of mines is well known; so that with such improvements as may be made in the course of years, we may fairly take 4,000 feet as a reasonable limit. Some persons anticipate the possibility of going down 5,000 feet, but the former figure will be adopted here.

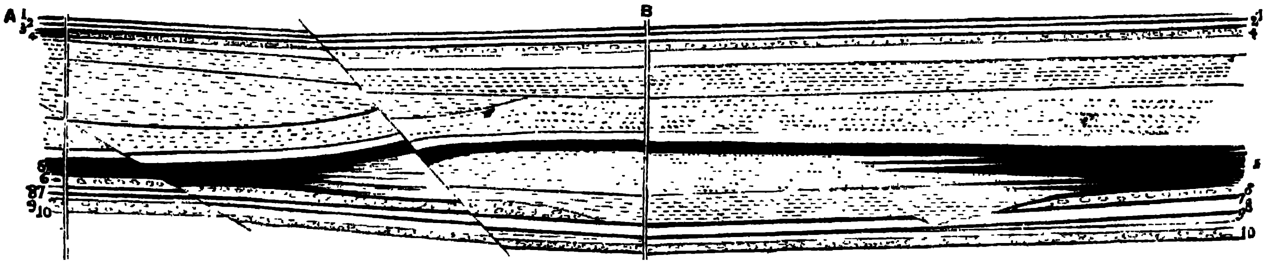


Fig. 5.—LOWER LEVELS OF THE BAREMOOR COLLIERY, SOUTH STAFFORDSHIRE. Scale, 1 inch = 176 feet.
1, the two-foot coal; 2, the Broach coal; 3, the Herring coal; 4, the Broach binds ironstones; 5, the thick coal; 6, the Grains and Gubbin ironstone; 7, the first Heathen coal; 8, black butt and fire-clay; 9, the second Heathen coal; 10, cake and white ironstones.

A very complete and careful series of observations on the increase of temperature was made years ago at Dukinfield Colliery (Cheshire), which favours the supporters of the lower level, as it was then found that the rate of increase was only equal to 1° Fahrenheit for every 84 feet from surface. The temperature at the great depth of 2,055 feet was only 75·5° F. It may be that some local circumstance favours the miner in this particular colliery; for it is not altogether borne out by similar investigations in other collieries, though they seem to indicate that the rate of progression in coal mines is scarcely so rapid as in others. At Wigan a temperature of 80° was recorded at a depth of 1,800 feet, and at Monkwearmouth a similar rate of augmentation has been registered—viz., 1° F. to every 60 feet. It is not unreasonable to suppose that considerable differences in temperature may be due to the nature of the rocks through which the shaft passes, so that it may hardly be right to compare a colliery in this respect with a Cornish tin mine; and for our present purpose we may fairly take 1° in 60 feet as our datum.

2. The thickness of workable coal in any coal-field is also, to some extent, a matter of opinion. It would be a simple affair if the coal were all in one seam, but that is not the order of Nature. In some coal-fields there are twenty seams or more; it rarely happens that there are less than four or five. There is no regular rule that can be laid down as to the limit in respect of thickness at which a seam of coal ceases to be workable. In some parts of the country much thinner seams are worked than at others; and there can be no doubt that an important increase in the value of coal would lead to the working of many thin seams which are now altogether neglected. Those only two feet thick have been worked before now in some districts, and probably the time will come when all such seams will be made use of, though on economical grounds that will not take place until the thicker seams are well nigh exhausted. Some seams, moreover, are very liable to change in this respect, so that the thickness observed in one working is no criterion for others even in the same neighbourhood. In Fig. 5, which represents the lower levels of the Baremoor Colliery, in the South Staffordshire coal-field, an illustration is afforded of the great changes which occur in what is known there as the "thick coal."

In the old pit marked A, the seam is 31 feet thick; at the new one, B, only 9 feet; while at the other end of the diagram, C, it is seen to be still thicker than at A. This cannot but be regarded as an extreme instance, for it is the thickest known seam in the British isles; but it is no uncommon thing for one that is well worth working in one pit, to thin off so much as to be of no commercial value whatever in a neighbouring colliery. Until, therefore, every seam has been thoroughly explored throughout all the coal-fields of Britain, this element of uncertainty must attach to all calculations.

3. The area of the coal-fields may be taken at about 4,500 square miles; but in many places coal is now worked beyond these limits, being overlaid by more recent strata; and if a depth of 4,000 feet be realised in practice, 1,000 square miles will probably have to be added to the previous figure.

4. The operations at some of the coal-fields are yet almost in their infancy, while others have seen their best days. Formerly the workings were carried on with less system and more wastefully than now, and some of those in the iron districts, such as the neighbourhood of Birmingham and Coalbrook Dale, have suffered very considerable exhaustion. Even in these there is still a large quantity of coal which can be saved by

judicious working. It will be evident, however, that in forming any estimate of the quantities remaining, each coal-field must be separately considered.

5. As to the probability of extending their area, and of opening up new fields, a considerable difference of opinion exists. This point can only be determined by actual borings. It has been found within the last few years that the superior strata in some parts of the midland counties are not so thick as had been supposed, and that the Carboniferous rocks are within a practicable depth. Nor is there any substantial reason why the workings should not be carried some little distance under the sea.

Adopting, then, the data furnished by the Geological Survey, and taking only those seams which are 2 feet thick and upwards, and which do not exceed 4,000 feet in depth, Mr. Hull arrived at the calculation that 79,843,000,000 tons of coal still remained available. Since he made his estimate, however, the odd 843,000,000 have been consumed.

The various coal-fields lie in patches extending from Gloucestershire and South Wales up to the extreme north of England; and in Scotland on both sides of the Forth and Clyde, and in Ayrshire. In Ireland there is a wide extent of Carboniferous rocks, but the beds of coal are very uncertain, and are only worked to a very small extent.

The South Wales coal-field covers an area of about 900 square miles, and the quantity of produce may be taken at about 16,000,000,000 tons. Its commercial value is considerably enhanced by its geographical position, having the Bristol Channel for its southern boundary, and by the fact of the coal seams being interstratified with bands of ironstone. The facilities for shipment of the coal at Swansea, Cardiff, Newport, and other ports, have led to a very large export trade; and the presence of iron ores in such abundance has created an immense demand for coal in the smelting and puddling works, and rolling mills. A peculiar feature of this coal-field is that the character of the coal materially alters as you proceed downwards, and from east to west. The seams at the eastern extremity are more or less bituminous, the upper being more so than the lower; in the middle of the coal-field they are semi-bituminous and anthracitic (the latter lowermost); and in the extreme west there is none but anthracite.

The Yorkshire and Derbyshire coal-field, extending continuously from Leeds through Sheffield, and nearly to Derby, is, including the coal-ground overlaid by more recent formations, more extensive than the preceding, and will yield at least as much coal. The produce of this great inland district is almost entirely consumed at home. In this region some very excellent iron ores are obtained, from which the best iron in the kingdom is made. The coal underlying the Permian and Triassic rocks on the eastern side of this coal-field has been worked as yet to only a very small extent.

The Newcastle field supplied London almost exclusively before the time of railways, the coal since brought to London by rail being principally raised in the midland counties. A very large quantity is exported to foreign parts, owing to the facilities of shipment at Newcastle, Sunderland, Hartlepool, and other ports. Both in area and in produce this is decidedly less than either of the two preceding, though about the double of any of the rest in England and Wales. It contains several valuable seams, each having its special advantages. One produces a strong semi-bituminous coal, very suitable for furnaces; another, the best quality of household coal; a third, a good gas coal, yielding also a very excellent coke. There is still some 7,000,000,000 tons of coal available in this district, though it has been worked for a very long period. It is traversed by a great whin dyke, which crosses the country in an east and west direction, on a line with the Tyne valley, by which the strata on the south side of the dyke are thrown down no less than 540 feet; the eastern end of this dyke may be seen to advantage at Tynemouth, where it juts out into the sea immediately on the north side of the harbour. Contrary to the rule which prevails so generally in other parts of the country, there is but little ironstone to be obtained in this coal-field.

The South Lancashire is the next in respect to size, and contains a very great thickness of workable coal; but it is troubled with numerous faults on a large scale. At Wigan, the cannel, which is very valuable for gas works, is three feet thick; but it gradually thins off in every direction from that point.

The South Staffordshire has already been mentioned as illustrative of the irregularity in the thickness of some seams. What goes by the name of the thick, or ten-yard coal, is, in fact, about a dozen different seams all united together. It generally runs about 30 feet thick; but at Foxyard's Colliery, near Dudley, it measures 39½ feet, including six thin partings of shale, the solid coal being equal to 36½ feet. At this spot, owing to considerable upheavings of the strata, the coal crops out at the surface, and for about 100 yards in length it is worked as an open quarry, with a face of 40 feet in height. It is the only instance in this country of an open coal-working upon such a scale. This is in the centre of the "Black Country," properly so called, a district almost wholly given up to the coal and iron trades. The consumption of coal at the iron works is now so great that, notwithstanding such a seam as this, the process of exhaustion is going on very rapidly, and there is scarcely 1,000,000,000 tons now left available in this field. There is one seam here which bears the inelegant but appropriate name of "stinking coal;" it is altogether neglected, as it contains so much sulphur that the fumes from it, if used for domestic purposes, would be intolerable, and it is absolutely useless for making iron, a very small admixture of sulphur being most injurious to this metal.

The less important coal-fields do not require separate notice. They are the North Staffordshire, the Bristol, the Forest of Dean, the Denbighshire, the Flintshire (which contains some very good cannel coal), and a few others.

The Scotch are important in more respects than one. The Clyde and Ayrshire fields actually join at some points, and they are one in their principal features. They furnish a strong slow-burning "splint" coal, which is associated with the celebrated black band ironstones, the splint being very suitable for the operations of the smelter. The notorious Boghead cannel also occurs in limited portions of this field; it is the best cannel in the whole kingdom, and is highly valued, though the seam only averages about 1½ feet thick.

The Leshmahago coal basin lies a little further to the south. It is of limited area, but is likewise rich in cannel of very excellent quality.

The total area of the Scotch coal-fields exceeds 1,700 square miles, and the available produce may be estimated at about 25,000,000,000 tons.

In Ireland Carboniferous rocks occur; but the coal is of no great value, and it is only worked to a small extent. The available quantity is too doubtful to justify its being included in the general total. At Kilkenny anthracite is the staple article.

SEATS OF INDUSTRY.—IX.

BY WILLIAM WATT WEBSTER.

MULHAUSEN.

Few manufacturing towns on the Continent of Europe have acquired a wider celebrity, or are better entitled to a place in a series of papers devoted to the description of the chief representative seats of industry, than the enterprising little town of Mulhausen, or Mulhouse, which has just been transferred from France to Germany, along with the province of Alsace and the German-speaking portion of Lorraine. For many years Mülhausen has taken rank as one of the principal centres of cotton manufacture in France, and its name has been associated with a variety of schemes for the amelioration of the condition of the working classes.

Mülhausen is situated in a fertile and well-watered district about sixty-one miles S.S.W. of Strasburg, and twenty-seven miles south of Colmar. It is divided into two parts, called old and new Mülhausen. The old town is built on an irregular oval-shaped island formed by the river Ill, which at this point separates into several branches, and is crossed by four bridges. The houses are substantial, and the streets are well paved and cleanly kept, although winding and rather narrow. Among the principal buildings in old Mülhausen may be mentioned the Reformed and Roman Catholic Churches, the Hôtel de Ville, and the College. The new town lies to the south-east of the old town, and extends from the right bank of the Ill to the Rhone and Rhine canal, which here expands into a spacious basin. It is laid out in wide, regular streets, lined with a superior class of houses. Mülhausen is an important station on the Strasburg and Basle Railway. The list of the institutions established in the new town includes a Tribunal of Commerce, a Consulting Chamber of Manufactures, a Conseil de Prud'hommes, an Industrial Society, and a Commercial College. In 1855 the population of Mülhausen numbered 28,715, and it is now estimated at about 45,000, the last census having shown that it contained 43,244 inhabitants. Lambert, the celebrated mathematician, was born in Mülhausen, and in the centre of one of the squares of the town which bears his name, a large column has been erected to his memory.

The leading facts in what may be called the political history of the town, so far as they have been handed down to us, may be told in a few words. Mülhausen is said to have been known to the Romans under the name *Ariabinum;* but our knowledge of the place at that remote period is confined to the mere name, and long centuries subsequently elapsed of which we have no record. It is, however, certain that Mülhausen was a considerable town in the thirteenth century, for it was erected into a free and imperial city by Rudolph of Hapsburg in 1273. The next event in the history of Mülhausen that merits notice was the adoption of the Reformed faith by the authorities and inhabitants of the town in the year 1523. For several centuries previous to 1798, Mülhausen was the capital of a small republic belonging to the Swiss Confederation; but in that year it withdrew from the Federation, and, renouncing its independence, became incorporated with France, and its connection with that country continued up to 1871.

The manufactures of Mülhausen were of little importance till after the middle of the last century and the introduction of cotton-printing and muslin fabrics, which took place about the year 1745. Prior to that date the manufacture of woollen goods was almost the only industry of the place. But the progress of cotton manufactures in the town was very rapid, and the cotton-prints and muslins of Mulhausen soon became noted for the pre-eminent excellence and unrivalled variety of their colours and patterns. In these respects the productions of the looms of Mülhausen challenge comparison even with the silk goods of Lyons; and not a little of the prosperity which this town has so long enjoyed must be ascribed to the artistic merits of its fabrics. In the numerous mills and factories established at Mülhausen and its neighbourhood, there are, however, a variety of goods manufactured besides those we have mentioned. The silks woven there, and especially the flowered silks, are held in the highest estimation. A very superior quality of woollen and fine cambric goods is also manufactured in large quantities, and there are very extensive mills for the production of cotton and woollen stockings. Mülhausen has besides a reputation for damask and other linens, carpets, straw hats, stained paper, starch, parchment, chemical products, and the common qualities of leather, as well as morocco. Large iron-works have long been in operation in the town and vicinity, and locomotives and other descriptions of steam-engines are constructed in great numbers. The tanneries, bleach-fields, and dye-works of Mülhausen are very extensive and its breweries and distilleries are held in high repute. There is a brisk trade carried on at Mülhausen, not only in the multifarious articles manufactured in the district, but also in raw cotton, wine, brandy, corn, and other agricultural products. The cotton manufactures of Mülhausen were very injuriously affected by the American Civil War of 1861-5, and it is to be feared that they have sustained another severe stroke by the events that have taken place in France since the 3rd of August, 1870. Before the Franco-Prussian war, however, the activity of the spinning-mills at this town had sensibly declined. The manufacturers of Mülhausen labour under the disadvantage of having to import their cotton by way of Havre or Marseilles, and the development of manufacturing enterprise in towns nearer the sea-board will doubtless tend to check, and may even eventually destroy, a large portion of the manufactures of the place. There are as yet few symptoms of decline. The manufacturers of Mülhausen have branch establishments in several parts of the Haut-Rhin and in the neighbouring departments, and till quite recently at least the amount of goods manufactured and exported was on the increase. A considerable proportion of the capital invested in manufacturing enterprise in Alsace is derived from Switzerland, and it is said that many of the mills and factories are heavily mortgaged to residents in Basle.

The work-people of Mülhausen did not always possess the many privileges they at present enjoy. About forty years ago the *Société Industrielle*, a body distinguished for its intelligence and patriotism, such as few manufacturing towns could boast of, drew up the following account of the state of the operatives in Alsace:—"They are allowed a quarter of an hour for breakfast and an hour for dinner, working for the most part from five o'clock in the morning till eight o'clock at night. Each family sleeps together in one room, which is either a cellar or a garret of the smallest dimensions. Their furniture is wretched, often only a miserable shake-down bed to accommodate all the family. They are very ill-clothed, often need the aid of the *Société de bienfaisance*, and are very dirty, especially in the spinning-mills. In the workshops obscene language and stories are often to be heard, which the children pick up with wonderful avidity, and repeat with a revolting zest." The next two sentences of the Société's report need not be translated. "Beaucoup des ouvriers," it continues, "vivent en concubinage. Ils appellent ces sortes d'unions *mariages à la Parisienne*, et en ont fait un verb allemand *parisiren*." In 1835 Mr. Andrew Ure, the author of the "Philosophy of Cotton Manufacture," visited Alsace while on a tour through the cotton factories of France and Belgium, and has left us an account of his observations and reflections, from which we shall make a few extracts. "Great misapprehensions," he remarked, "prevail concerning the physical and moral condition of the factory operatives abroad, especially in the fertile region of Alsace. They have been represented as being mostly Protestants, and in very comfortable circumstances. There can be no greater mistake. Among the multitude of factory proprietors in Alsace there is only one Protestant.. The working classes are devotees of the Romish communion." A little further on in the same work occurs the following passage on the condition of the Mülhausen operatives:—"If Sunday be a day of rest and tranquil pleasure to those who work in a moderate manner through the week, it is, on the contrary, a day of debauchery and orgies to those who, having been kept at labour beyond all reasonable bounds, take that occasion to riot in their liberty. Hence it is not uncommon here to see drunkards of from twelve to fifteen years of age. Their degree of instruction is very slender. All their physical, and in consequence all their intellectual, faculties are exhausted by toil. Certain enlightened proprietors have established, at their own expense, schools within their mills at Mülhausen, and especially M. Naegely. The cruel conduct of parents in sending their children at an almost infantine age to the factory, seldom fails to entail fearful retribution; for whenever the children discover the mercenary bargains of which they have been made the victims, they take the first opportunity of renouncing their filial engagements, and of abandoning their parents. And this alienation in the family, aggravated often by the brutality and ignorance of its head, is one of the main causes of the misery which prevails among multitudes of the work-people. The operative spinners of Mülhausen are generally pale, and subject to chronic catarrhs, which degenerate often into phthisis. The piecers and card-tenters sometimes lose the first joint of their fingers. The weavers are often seized with chronic rheumatism."

Such was the moral and physical condition of the vast majority of the factory operatives in Alsace at the time when Mr. Ure visited them; but several of the mill proprietors in that district had already began to show consideration for the welfare of their work-people. It is pleasant to turn from the dark picture suggested by, rather than delineated in, these extracts, to another passage in Mr. Ure's notes of his tour, descriptive of the great manufacturing establishment of Messrs. Gros, Divillier, Roman and Co., at Wesserling, in one of the most beautiful valleys of the Vosges mountains. This is pronounced by Mr. Ure to be "the most picturesque, peaceful, and well-ordered manufactory" he had ever seen, and he waxes quite eloquent in its praise. With the word-painting and the landscape we are not at present concerned, and so we shall pass at once to the substantial and economical portions of Mr. Ure's narrative. "The works of Wesserling," he tells us, "consist of cotton mills, power and hand weaving of calicoes and muslins, bleaching grounds, and print-works. The calico-printing was commenced as far back as the year 1760. The spinning mill, the loom shops, the bleach fields, and cylinder press rooms date from the year 1802. The establishment is placed at a distance of two leagues from all towns, and is the central point of nine villages, containing a population of from 12,000 to 14,000 souls. There is no other manufactory within a league of it. Feelings of philanthropy presided at the origin of Wesserling. The first founders had for one of their objects to give comfortable employment to the natives of the valley, and they have been regarded by an invincible attachment on the part of their work-people. Most of them (the operatives) are proprietors of a house and a little land, which their families cultivate, and the whole of them have rights to the use of the pasture-common. Their chief agriculture is that of the potato and meadow-grounds, and they all possess cattle. They are Roman Catholics, while their masters are Protestants of the Genevese church; but both live in the mutual charities of religion. The language of the country is still German as of old, and the temperament of the people is a little phlegmatic but docile. Their intelligence may be developed with a little pains, especially that of the female sex. The proprietors founded, sixteen years ago, a savings' bank for the operatives, which pays five per cent., and they study to persuade the youths to deposit. The work-people have benefit societies managed by themselves; but as the state of wages and employment seldom varies, they do not suffer from the vicissitudes of trade. A skilful medical man attached to the establishment attends gratuitously the workers and their families. Each of the villages has one or two well-conducted schools, and at Wesserling itself there is an upper school, erected by the public authorities as the model seminary of the canton."

It is within the last twenty years that the most successful efforts to improve the circumstances and character of the working classes of Mülhausen have been made. In the year 1853, the first Association for the erection of "cités ouvrières," or workmen's towns, was founded at Mülhausen, with a capital of 300,000 francs, in sixty shares of 5,000 francs, or £200 each. The State contributed 300,000 francs to assist the undertaking; the whole of which sum had to be laid out in streets, side-paths, sewers, fountains, plantations, baths, wash-houses, and bakeries. In order to convey an idea of the immense benefit this association has conferred on the community of Mülhausen, it may be stated that it has built about 700 houses, affording accommodation to a population of some 5,000. These houses are of various descriptions and dimensions, some consisting only of a ground-floor, while others have a storey. They are planned to meet the requirements of health, comfort, and decency; and each house has a garden attached to it. In a large number of cases, the working man is the proprietor of the house in which he resides. The method by which this is accomplished deserves to be detailed. A house with a ground-floor only costs 2,650 francs, or £106, and a house with an upper floor costs from 3,300 to 3,400 francs. The Association sells its house to the workman at cost price, and the purchaser begins by a payment of 300 francs, or £12, which is kept in reserve for the expenses of the contract, or is returned in the event of the purchaser being obliged to withdraw from the bargain, or unable to pay up the remainder of the price. When the last-mentioned contingency occurs, the Association repays to the purchaser the difference between his deposit and the claim it would have had against him if he had simply been a tenant. In all cases where a sale is agreed on, the purchaser is put in occupation, and by a payment of from 18 to 25 francs per month for a few years, according to the contract, he becomes the owner of the house. This monthly payment, it will be seen, is little more than an ordinary tenant would be charged as rent. When the Association merely lets its houses, it charges rent at the rate of 8 per cent. on the cost of the tenement; but the shareholders are bound by their charter not to take more than 4 per cent. interest on their money, and any surplus revenue that may be got pays for insurance, taxes, and repairs. The "cités ouvrières" of Mülhausen have proved so beneficial that the scheme has been adopted in Paris, and in other French towns. With the improvement in the material condition of the work-people of Alsace effected by Associations for the construction of workmen's towns and kindred movements, a corresponding moral advance has been made. But there is little of a distinctive character about the trade unions, co-operative and friendly societies of Mülhausen, and it is not necessary to describe them in the present article.

The Franco-German war was a critical period in the history of the town, and it is to be hoped that the energy and enterprise which have so long distinguished its inhabitants will enable them to surmount the difficulties in which they were consequently involved.

BUILDING CONSTRUCTION.—XV.

OF ROOFS GENERALLY.

THE term *roof* seems derived from the Saxon word *hrof*, or, perhaps, a contraction of the German words *Hier-auf* (upon here), and, as is well known, means the cover or top of a building, generally consisting of two sloping sides, though occasionally of other figures.

The ancient Egyptians, Babylonians, Persians, as well as other Eastern nations, had their roofs quite flat. The Greeks appear to have been the first who made their roofs with a slant each way, from the middle to the edges. This was very gentle, the height from the ridge to the level of the walls not exceeding one-eighth or one-ninth of the span, as may be seen by many ancient temples now remaining. In Northern climates subject to heavy rains and falls of snow, the ridge must be very considerably elevated. In most old buildings in Britain, the equilateral triangle seems to have been considered the standard both in private and public edifices, and this pitch continued for several centuries till the disuse of what is called Gothic architecture. The ridge was then made somewhat lower, the rafters being *three-fourths* of the breadth of the building. This was called the *true pitch;* but subsequently the half-square seems to have been considered the true pitch.

The heights of roofs were gradually depressed from the half square to one-third of the width, and from that to a fourth, which is now a very general standard, though they have even been executed much lower.

There are some advantages in high-pitched roofs, as they discharge the rain with greater facility; the snow continues a much shorter time on the surface; and they are less liable to be stripped by heavy winds.

Low roofs require large slates, and the utmost care in their execution; but they have the advantage of being much cheaper, since they require timbers which are shorter and of less scantling. When executed with judgment, the roof is one of the principal ties to a building, as it binds the exterior walls to the interior and to the partitions, which act like strong counterforts against them.

Roofs are of various forms, according to the nature of the plan, and the law of horizontal and vertical sections. The most simple form of a roof is that which has only one row of timbers arranged in an inclined plane, which throws the roof entirely on one side; this is called a "lean-to" or shed roof (Fig. 141).

The most general roof for an oblong building consists of two rectangular planes of equal breadth, equally inclined, and terminating in a line parallel to the horizon. Consequently, its form is that of a triangular prism, each side being equally inclined to the plane of the wall-head; this is generally called a "pent roof." Fig. 142 is the end view, or "gable," and Fig. 143 is the plan of such a roof.

When the plan is a trapezium, and the wall-heads properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge. The sides, therefore, instead of being planes, are made to wind in order to have the summit parallel to the horizon; but the most eligible method is to make the sides of the roof planes, enclosing a level space or flat, in the form of a triangle or trapezium, at the summit of the roof.

Roofs flat on the top are said to be *truncated.* These are chiefly employed with the view to diminish the height, so as not to predominate over that of the walls.

When all four sides of the roof are formed by inclined planes, it is called a "hipped roof" (Figs. 144 and 145), in which case two of the inclined sides—namely, those which slant from the long sides of the building—will be *trapezoids*, and the other two *triangles*.

But if the building to be covered be *square* (Figs. 146 and 147), and all the slides slant equally, the roof will form a square pyramid, for the projection and development of which see lessons in "Projection."

A building having a hipped roof consists of a square prism, on which a triangular prism rests, but the ends of the prism are slanted off.

When the planes of roofs, instead of being continued until they meet in a ridge, take another slant at a certain height, they are called "curb" or "Mansard" roofs (Fig. 148), from the name of their inventor, a great French architect* who lived in the sixteenth century. They are much employed in France, and are hence often called "French roofs." When the plan of the roof is a regular polygon, a circle, or an ellipse, the horizontal sections being all similar to the base, and the vertical section a portion of any curve, convex on the outside, the roof is called a *dome.*

We will now enter more particularly into the construction of a roof, in order to explain the principles which guide the designer, and to give the names of the different timbers employed.

It has already been stated that a badly-designed roof may prove the ruin of an entire building by forcing the walls outward; whereas, if constructed on correct principles, it will tend to tie them together, and so give firmness to the whole structure; and it has also been mentioned that the most generally adopted roof is that formed by two inclined planes; but it will at once be seen that this must be very limited in its application, and could only be used with anything like safety where the walls are very strong so as to resist the pressure of the roof; for it must be clear that the weight of the timbers and slates or tiles would tend to force the walls out of the perpendicular. This will be understood on referring to Fig. 149.

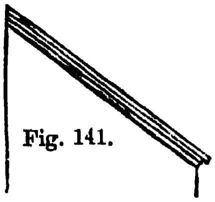


Fig. 141.

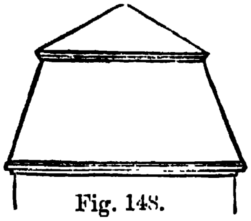


Fig. 148.

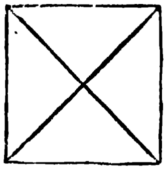


Fig. 147.

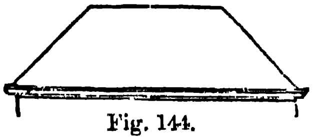


Fig. 144.

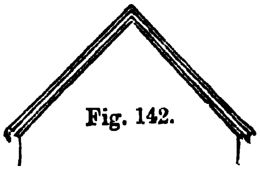


Fig. 142.

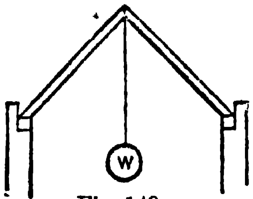


Fig. 149.

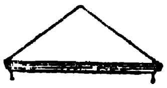


Fig. 146.

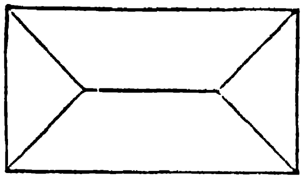


Fig. 145.

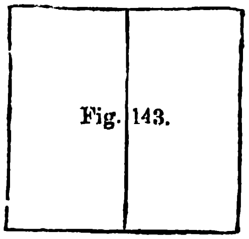


Fig. 143.

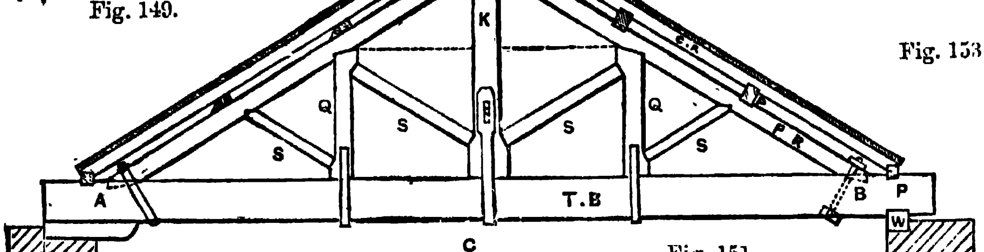


Fig. 151.

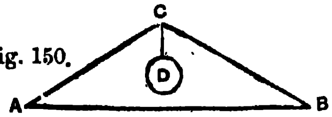


Fig. 150.

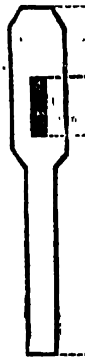


Fig. 153.

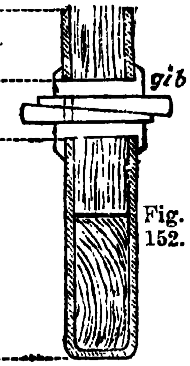


Fig. 152.

Now when this force (W) came into action, it would spread the feet of the rafters outward, and therefore the obvious remedy is to *tie* them together. Thus a *rope* would, to a certain extent, answer the purpose; but instead of tying the feet of the rafters together, they are mortised into a beam called the *tie-beam*, in such a manner that they cannot spread outward, and this is the first step towards the proper construction of a roof. Wall-plates have already been mentioned. They are timbers laid on the tops of the walls to prevent the roof-trusses pressing on one particular part, and to spread the pressure along the whole length. Resting on these, and crossing the entire width of the building, the long timber *tie-beam* is placed; and the very manner of placing it is such that any weight pressing on it may bear downward and not outward, and thus it ties the walls together; into this the rafters are mortised, in one or other of the methods already shown.

The rafters are not allowed simply to meet at the top, but abut against the slanting part of an upright, called the *king-post*, the purpose of which must not be misunderstood.

Casual observers might imagine that the king-post rests upon the tie-beam, and supports the rafters at their junction; but it does no such thing, the rafters abutting against the tie-beam meeting at the top and forming a triangle, because the two sides together are greater than the third ("Euclid," Book I. Prop. 20), and the third in this case is the tie-beam. Now, in the triangle A B C (Fig. 150), the weight D could be suspended; and as the two sides A and B meet in C, C becomes, as it were, the keystone of an arch, and firmly supports the weight D suspended from it.

Thus then, in Fig. 151, the points A and B act as the abutments of an arch, and the head of the king-post, K, is the keystone into which the upper ends of the principal rafters, P R, are mortised; and thus, the more the keystone be pressed down, the firmer will the structure be. But the weight of the roof does not really press upon the keystone, but upon the rafters, and these again transfer their force to the tie-beam, T B. Now, at its ends, the tie-beam is well supported, but in most cases is liable to sag, or sink in the middle; and if this were to occur, the ends of the rafters would be drawn inward, and with them the walls on which the wall-plates rest. The king-post is therefore a continuation of the keystone, and comes just down to, but does not rest upon, the tie-beam, which is therefore strapped up to the king-post by an iron band; and thus, instead of the tie-beam supporting the king-post, the king-post supports the tie-beam, the middle portion of which is suspended from it.

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* Francis Mansard, an eminent French architect, born at Paris in 1598, was the son of the King's carpenter, and received those instructions which led to his eminence as an architect from Gautier; but for the high rank to which he attained in his profession he was indebted to the force of his own genius: he died in 1666. His nephew, Jules Hardouin, became a great favourite of Louis XIV., and was enabled under his patronage to realise a large fortune. Amongst his principal works were the Château de Clugny and the Palace of Versailles. He died suddenly at Marly in the year 1708.

In order to tighten up the tie-beam, an opening is pierced through the upper ends of the iron strap, and through the king-post. Iron "gibs" are passed through this hole, and two iron wedges entering from the opposite sides are driven in. It will be evident that the effect of this will be to draw up the strap, and with it the tie-beam around which it is placed. Fig. 152 is a section showing the king-post, tie-beam, iron strap, gibs, and wedges, and Fig. 153 shows the front of the strap.

All the parts referred to will be seen in their places in Fig. 151, in which are also shown struts, S, S, which, abutting on the foot of the king-post, support the principal rafters, P R, at a point between their upper and lower ends. If the width require that the beam should be further braced up, the struts S, S, then, instead of being mortised directly into the rafters, serve to support two posts smaller than the king-post, but of the same character, called *queen-posts*, Q. To these, again, the tie-beam is strapped up as in the former case. Against their feet struts abut, supporting the rafters; and it will be seen that this system may be carried on as long as the nature of the materials would permit; the whole truss resting on the wall-plates, W.

Now it will be clear that such strong and heavy assemblages of timber as these roof-trusses need not necessarily be placed close together, being intended as the main supports of the whole covering of the building; further framing is therefore necessary, in order that the intermediate spaces may be properly and securely roofed over. This is done by throwing timbers at intervals across the trusses. These are called "purlins," P, and are sometimes "notched" on the principal rafters, as at P, on the right side of the drawing, or rest against blocks, as shown at the corresponding point on the left side; the latter is to be preferred, as the principal is not weakened by the removal of any part of the thickness. Thus a horizontal framework is created, and across these, at about a foot apart, smaller timbers called "common" rafters are placed, C R. These either abut on a timber called the pole-plate, *p*, resting on the end of the tie-beam, outside the insertion of the foot of the principal rafters, or may be notched on to it, and passing by it, may form the eaves, or projecting part of the roof, under which a gutter may be placed. Across the common rafters strips of wood called "battens" are nailed, and to these the slates are attached; or, in cases where the inside of the roof is to be left visible, it is covered in with boards, to which the slates are nailed. The interior of these boards, and the timbers on which they rest, are then stained and varnished: and such roofs have a beautiful appearance, especially when the lines are such as to show the scientific principles upon which the whole is constructed. The open timber roof of the Middle Ages forms one of the most beautiful features of that period of architecture. They were, in the first instance, constructed on the most perfectly correct principles of science. They were then, in some cases, elaborately carved and filled in with most exquisite tracery, or were painted. The construction was not *concealed* by ornament; but, on the contrary, the decoration served all the more to show the construction to advantage. And we can thus feel the truth of Mr. Brandon's words: "A timber roof of the fifteenth century, with its massive timbers elaborately wrought; its rows of hammer-beams, terminating in beautifully-carved figures of angels; its enriched panelling and traceried spandrils; its exquisite bosses; and, above all, its profusely-ornamented cornice, is truly as glorious a sight, as it is a grand triumph of the carpenter's art. Such excellence, however, was but very gradually accomplished."*

In some cases the heads of the queen-posts are kept apart by a horizontal timber (shown by a dotted line in Fig. 151) called the *straining beam*, which is strapped up to the king-post, which in such a roof-truss would not come down to the tie-beam. The subject of roofs in timber and iron is of such importance, and its elucidation requires such numerous illustrations, that a separate series of lessons will be devoted to it in THE TECHNICAL EDUCATOR.

The leading principles of the construction of roofs covering a span of great width are exemplified in the complex structures by which our large railway stations and termini are covered in, and which may be studied with advantage.

VEGETABLE COMMERCIAL PRODUCTS.

XVII.

PLANTS PRODUCING VALUABLE GUMS, RESINS, AND BALSAMS (*continued*).

TURPENTINE PINE (*Pinus palustris*, Wild., and *Pinus Tæda*, L.; natural order, *Coniferæ*).—The importation of turpentine by other nations is not very considerable, since almost every country possesses trees from which it may be procured. England, however, is an exception, the demand for turpentine being much greater than the home supply. We receive nearly all our turpentine from the United States, and it is obtained from the above two species of *Pinus*. There are also in the market, Bordeaux turpentine, obtained from *Pinus pineaster*, Aiton; Strasburg turpentine, from *Abies pectinata*; Venice turpentine, from *Abies larix* (Rich.), the common larch; and Chio turpentine, from the *Pistacia terebinthus* (L.), a tree indigenous to Cyprus.

The process of collecting turpentine is in each case nearly the same. The bark of the trees being wounded, the turpentine trickles out in drops into boxes or other vessels placed so as to receive it. The incisions are made about the close of the month of March, and the turpentine continues to flow throughout the vegetative season, particularly during the summer months.

Turpentine is imported in barrels, weighing from two to two and a-half cwt., and has the appearance and consistence of honey. Oil or spirits of turpentine is obtained by distillation from the raw turpentine; this residue is the common resin or rosin of the shops. Spirits of turpentine, as a solvent of all resins, is much used in the preparation of paint and varnish; and rosin in the manufacture of common soap, common sealing-wax, for the bows of violins, and for caulking ships.

In 1863, 27,343 tons of turpentine, valued at £31,274, were imported into the United Kingdom, chiefly from North America.

GUM-ARABIC (*Acacia vera*, Wild., and *Acacia Arabica*, Wild.; natural order, *Leguminosæ*).—Gum-arabic is produced by these two trees, which grow in abundance in Arabia, and in Egypt on the banks of the Nile. It flows spontaneously from their trunks and branches, in the form of a mucilage, which dries and hardens on exposure to the air. The more sickly the tree, and the hotter the weather, the more abundantly exudes the gum. It is very nutritious, and the Arabs who gather it almost live upon it during the harvest.

The principal African and Arabian ports for the exportation of gum-arabic are Aden, Mokha, Suez, Cairo, and Alexandria. Gum-senegal, the product of *Acacia Senegal* (Wild.), is the best and dearest sort of Arabian gum. It is distinguishable from gum-arabic by its clearness, consisting of choice drops of tears, some as large as a pigeon's egg, entirely white, and shining like glass. Gum-tragacanth, which is yielded by *Astragalus tragacantha*, L., is also considerably in demand, and is one of the chief gums of commerce. We receive this gum from Greece and Asia Minor. The principal place for its exportation is Smyrna.

These gums are chiefly used in the manufacture of silks, crapes, and muslins, to stiffen and glaze the fabric; they are employed also in calico-printing, to give consistence to the colours; in medicine, painting, and in the manufacture of ink. The quantity imported in 1850 was 1,984 tons, of which 328 tons were gum-senegal.

GUM-SANDARACH (*Callitris quadrivalvis*, Verst.; natural order, *Coniferæ*).—This tree is a native of Barbary, on the African coast. The Turks construct the ceilings and floors of their mosques of its wood, which is all but indestructible. The gum, which is much used in making fine varnishes, is imported to the extent of from twelve to fifteen tons annually.

GAMBOGE (*Hebradendron gambogioides*, Grah.; natural order, *Clusiaceæ*).—Gamboge is a gum-resin obtained from this tree, which grows wild on the Malabar and Ceylon coasts. In Ceylon gamboge is obtained by wounding the bark of the tree as soon as the flowers begin to appear. It appears in commerce in three forms—in solid rolls or cylinders, in hollow rolls or pipes, and in amorphous masses or cakes. Gamboge is imported from Ceylon, Siam, and Cochin-China. The best is the pipe-gamboge from Siam.

Gamboge is employed as a water-colour or pigment by artists, also in medicine as a drastic purgative. Our imports were—in 1863, 388 cwt., valued at £3,268; and in 1864, 42 cwt., valued at £520.

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* The whole subject of Gothic Architecture will be treated of hereafter in this work in a separate series of lessons.

Camphor Tree (*Laurus camphora*, L.; natural order, *Lauraceæ*).—The camphor tree is a native of China, Japan, Borneo, and the island of Formosa. Camphor—a gum-resin—is obtained as follows:—"The wood of the *Laurus* is cut into small pieces, and put, with plenty of water, into small iron boilers, which are covered with an earthen dome lined within with rice straw. As the water boils the camphor rises with the steam, and attaches itself as a sublimate to the stalks, under the form of granulations of a grey colour. In this state it is picked off the straw, and packed up for exportation to Europe." *

Camphor is brought to this country in chests, drums, and casks—in small granular, friable masses, of a dirty-white or greyish colour. It is much used in museums and private collections of natural history, as a preservative of animal and vegetable bodies against the depredations of insects. It is also used in medicine, in the composition of varnishes, and in the manufacture of fire-works. The total amount annually received from China and Japan is about 466,000 pounds.

Frankincense (*Boswellia serrata*, Roxburgh; natural order, *Amyridaceæ*).—This is an odoriferous gum-resin, much used by the Roman Catholics in their churches. It was employed by the priests of ancient Egypt to conceal the unpleasant emanations arising from the sacrifices offered in their temples. It is imported from India and the Levant.

Asafœtida (*Narthex asafœtida*, Falconer; natural order, *Umbelliferæ*).—This fetid gum-resin exudes from incisions made in the roots of the plant. It is first a milky juice, but when dried in the sun, acquires a mottled appearance and a pink colour. The plant is indigenous to the south of Persia, Affghanistan, and the Punjaub. Asafœtida usually comes over in casks and cases. It is much used in medicine as a valuable stimulant and anti-spasmodic, in cases of asthma and spasmodic cough.

VI. THE BARKS OF COMMERCE.

Many varieties of bark are known in commerce, the chief of which are those used for medicinal purposes, such as the Peruvian and Cascarilla barks; and economic barks, employed in the arts and manufactures, such as the bark of the cork oak, and the valuable tanning bark of the common oak.

MEDICINAL BARKS.

Peruvian Bark (*Cinchona Condaminea*, Humb. and Bonpl., etc.; natural order, *Cinchonaceæ*).—Peruvian bark is the product of various species of Cinchona, a group of evergreen trees and shrubs growing on the slopes of the Andes in Peru and Bolivia, at elevations varying from 7,000 to 10,000 feet above the level of the sea.

The medicinal properties of this bark are entirely owing to the presence of three alkaline and bitter principles—quinine, cinchonine, and quinidine—which are the most effective remedies known against intermittent and allied fevers. The Jesuit missionaries were the first to discover and make known its value as a remedial agent, and for a long time they were the sole vendors of it, whence its name of "Jesuit's Bark." The generic name *Cinchona* was given to the plant because, in 1638, the Countess of Cinchona, wife of the Viceroy of Peru, was cured of intermittent fever by its use; hence also, the powdered bark was called *Pulvis Comitissæ*, or Countess's powder.

There are, at the fewest, twelve species of *Cinchona* from which the Peruvian bark of commerce is derived. All these resemble each other in their general features; having opposite leaves, which are shining, lanceolate, on short petioles, and small, tubular, and white or rose-coloured flowers, arranged in ample panicles at the extremities of the branches. The principal varieties of Peruvian bark recognised in the Pharmacopœia are the *pale*, the *yellow*, the *red*, and the *crown* bark. Pale or *grey* bark is obtained from *Cinchona nitida* and *C. micrantha*; Loxa or crown bark, from *C. Condaminea*; yellow or Calisaya bark is yielded by *Cinchona Calisaya*; the source of the red bark is not yet ascertained. The pale bark contains most cinchonine, the yellow most quinine; Loxa or crown bark, the largest proportion of quinidine; the red yields the alkaloids in about equal proportions.

Peruvian bark comes to us in the form of quills or hollow cylinders, which vary in length and diameter, the longest seldom exceeding two feet—the diameter varying from a quarter of an inch to two inches. These quills are the bark of the smaller branches of the tree, which rolls up thus as it dries in the sun. Pale black arrives in quills only; the Calisaya or yellow bark, and also the red bark, comes both in quills and flat pieces, which last are derived from the trunks, and reduced to this form by being alternately exposed to the sun and then subjected to pressure until perfectly dry. Peruvian bark is usually imported in packages, or *serons*, made of dried cow-hides. The annual imports into this country amount to between 80 and 90 tons. The cinchona plant has been introduced with every prospect of success into British India, where large plantations are now established in many of the hilly districts; and more recently into Japan and the Mauritius.

Cascarilla Bark (*Croton Eleutheria*; natural order, *Euphorbiaceæ*).—This tree is a native of St. Domingo, the Antilles, and the Bahama Islands. Its bark is imported chiefly from Eleuthera, one of the Bahamas, and comes in small-sized quills and in chips. Cascarilla bark has strong aromatic and tonic properties, and is an excellent remedy in chills and fever, being occasionally employed as a substitute for cinchona. When burned it gives forth a sweet musky odour, and is often used in fumigations. The amount annually received in this country is from ten to twelve tons.

Cedron (*Simaba cedron*, Aubl.; natural order, *Simarubaceæ*).—The cedron is a small tree confined to the republic of New Granada, ranging from about the 5th to the 10th degree of north latitude. Every part of the plant, but especially the seed—owing to the presence of an alkaloid (*cedrine*)—is intensely bitter. On account of this principle, it is used extensively, and with considerable success, in cases of intermittent fever. But the chief reputation of the cedron rests upon its being considered an efficacious antidote for the bites of snakes, scorpions, centipedes, and other noxious animals; and so highly do the natives of the land in which it grows value it, that they will pay a large price for a single seed.

Quassia Amara, belonging to the same order as the cedron, is also a valuable febrifuge.

VII. TANNING MATERIALS.

In the bark of certain trees a peculiar light yellow glistening substance exists, called *tannin*, or tannic acid, which consists of small yellow crystals. This tannic acid has the power of combining with the gelatine in the skins of animals, and converting them into leather by forming a tannate of gelatine. The most valuable bark for this purpose is that of

Oak (*Quercus pedunculata*; natural order, *Cupuliferæ*).—Indigenous to this country, and also much cultivated. We import large quantities of oak bark from Holland and Belgium. In 1852 we received 19,034 tons, whilst the home produce was 150,000 tons.

Valonia (*Quercus ægilops*).—Under this name the acorn-cups of this species of oak are used; although the tree is dwarf and shrubby, these cups are very large and much prized by tanners. Large quantities are imported from the Levant, chiefly *viâ* Smyrna, not less than 29,396 tons having been received in 1866. Sometimes the acorns are gathered before they are fully formed; they are then called *camata*, or *camatina*. In this state they are more valuable, but too expensive to be largely employed.

TECHNICAL DRAWING.—XXIX.

DRAWING FOR MACHINISTS.

ISOMETRICAL PROJECTION.

The principles of isometrical projection having already been given in previous lessons (Vol. I., page 267), it is not necessary to repeat them here; it will be sufficient to remind the student that the square A C B D (Fig. 267) is represented in isometric projection by the lozenge A′ C *b* D.

From this figure it will be seen that the side D B of the square is at 45° to D E, whilst the side D *b* is at 30° to D E.

The difference, then, between the triangle D E *b* and the triangle D E B is the triangle D *b* B, the angle *b* D B being 15°, and D B *b* being 45°.

It will therefore be plain that if the side of a cube be given, and we are required to find the side of the hexagon which would form the isometric projection of it, we need only take the length as the basis of a triangle, as D B, at the one end construct an angle of 30° (that is, an angle similar to B D *b*), and at the other an angle of 45° (similar to the angle *b* B D). This triangle then, as said before, will represent the side of the cube and its isometric projection.

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* Ure's "Dictionary of Arts, Manufactures, and Mines." Vol. I. London, 1867.

The side D *b* of such triangle will be the required length of the side of the hexagon, and any divisions or parts marked on B D, as B *f*, may be transferred to *b* D by drawing a line from *f* parallel to B *b*, cutting *b* D in *g;* then *b g* will have the same proportion to *b* D that B *f* has to B D.

CONSTRUCTION OF AN ISOMETRICAL SCALE.

Although the method of constructing the isometrical scale has been given in a former lesson (Vol. I., page 269), it is repeated here for the convenience of the student, to save the trouble of reference to another volume.

Let it be required to construct an *isometrical scale* of $\frac{1}{12}$—that is, 1 inch to the foot.

Fig. 268.—Draw the line A B, and A C at an angle of 15° to it. It will be found convenient to draw an angle of 30° by means of your set-square, and to bisect this angle.

From A set off any convenient number of inches to represent feet, as A D, D E, dividing any one of them into 12 equal parts, as D E.

Now from E draw a line at 45°, cutting A C in F.

From all the points of division, 1 to 12, draw lines parallel to E F, and these will give on A C the divisions contained between G and F, which will represent the twelfths of inches in the isometrical measurement.

Fig. 269 is an isometric projection of a square case divided into compartments.

Let A be the position of the nearest angle of the object to be projected.

On each side of A draw a line with the set-square of 30° placed against the T-square. This will at once give the angle B A C (120°) which will be formed in the isometrical projection by the meeting of two lines at right angles to each other.

Now the measurements of this case are as follow:—General front elevation, 2′ 1″ square; depth, 5″; thickness of wood, 1″; width of compartments, 7″.

On A erect a perpendicular. Make A D and A B 2′ 1″ by the isometric scale. Draw D E parallel to A B, and B E parallel to A D. This will complete the isometrical projection of a vertical square, which would be the left side (A) of the cube shown in Fig. 270. From D and E draw lines parallel to A C. On A C set off the depth of the case—viz., 5″—and erect a perpendicular cutting the line drawn from D in F. From F draw a line parallel to D E, cutting the line drawn from E in G. This will complete the projection of the object treated as a block only.

Now it will be clear that, as the thickness of the wood is to be 1 inch, and there are to be three compartments in width, and three in height, these will be 7 inches each; therefore, along A B and A D, set off an inch for the thickness of the case, then a space for the compartment, an inch for the thickness of the board dividing the compartment, and so on.

From these points lines drawn parallel to the sides of the figure will complete the projection of the front of the case.

Now from each of the inner angles joining the planes of the sides of the compartments which would be visible, draw lines parallel to A C.

From the points on A D, marking the thickness of the shelves, draw lines parallel to A C, cutting C F in H, I, etc.

From these points draw lines parallel to A B; these, cutting the lines already drawn from the inner angles of the compartments, will give the distant inner angles at which the perpendiculars form the back edge of the upright divisions, and the projection will thus be completed.

Fig. 271 is the isometric projection of a *wooden stand for a machine*. It is drawn to the same scale as the last, $\frac{1}{12}$, the dimensions being as follow:—Length, 3 feet; breadth, 1′ 10½″; height, 2′ 5½″; thickness of legs and rail, 3″.

The lines A B (3 feet) and A C (1′ 10½″) having been drawn at the angle of 30° to a horizontal line, the lines B D and C D are to be drawn parallel to A C and A B respectively.

On each side of A, and inwardly from B and C, on the lines A B and B C, set off three inches representing the thickness of the legs—viz., E, F, G, and H.

From these points draw lines parallel to those already drawn, and these will complete the plan of the stand, giving not only the boundary lines of the space covered by the object, but also the projections of the square spaces in which the legs will stand; and this is one of the advantages of isometrical projection, in which the objects are worked without a separate plan or elevation, the drawing uniting in itself plan, elevation, and projected view.

It is not always necessary in practice to project the whole plan, but in the present case it is required in finding the inner sides of two legs, and the position and width of the distant one.

Thus the lines drawn from G and H, intersecting, give the point I, and being carried beyond this point they cut B D and C D in J and K, thus completing the plan of the distant leg.

Again, G J in passing through the line drawn from F gives the point L, whilst the line drawn from E, cutting H K, gives M, the position of the perpendicular for the inner side of the leg.

Now from A, B, and C erect perpendiculars.

Make A O 2′ 5½″ high, and from O draw lines parallel to A B and A C. These will cut the perpendiculars drawn from B and C in P and Q. The perpendiculars B P and C Q will necessarily be the same height as A O.

From P and Q draw lines parallel to O P and O Q, which intersecting in R will give the projection of the outline of the top of the object.

Draw perpendiculars from E, F, G, and H to meet the lines O P and O Q in S, T, U, V. From these points, lines drawn parallel to the sides of the external figure will give the projection of the top of the stand corresponding precisely with the plan.

From O set off O W, representing the depth of the upper rail —6″ by scale—and from W draw lines parallel to the sides of the object. The line drawn from W on the left side will cut the perpendicular H U in X, and similarly the line drawn from W on the right side will cut the perpendicular G V in Y.

Lines drawn from X and Y parallel to A B and A C will intersect in Z, and give the lower edge of the inner surface of the two distant rails.

The intersection Z will, if the work has been accurately done, fall on the perpendicular from I, the inner edge of the distant leg. Perpendiculars from J and K may now be drawn, and the cross-stay may also be added, thus completing the projection.

Fig. 272 is an isometrical projection of a simple *circular solid penetrated by a square prism*, showing the principles on which a wheel would be projected isometrically.

It will be remembered that projection does not deal with circles or curves as such, but requires that they shall be enclosed in rectilinear figures, across which diagonal or other lines are drawn. These figures are then projected, and the circles or curves are drawn through the points corresponding to those through which they would pass in the original figure.

Fig. 273 is a quarter of the circle about to be projected, enclosed in a square which would represent one quarter of the square required to contain the whole circle.

Now, as a rule, the thickness of the square solid to be projected would only require to correspond with that of the wheel; but in the present case the length of the penetrating prism or axle corresponds with the diameter of the circle, and the containing block would therefore be the cube A B C D E F G.

In the middle of the side A E the thickness of the wheel H is to be marked, and the perpendiculars H J and I K having been drawn, the square slab which would contain the wheel is to be projected.

Now the whole square containing the circle would require that diagonals should be drawn across it; therefore in the square *j l m m′* (Fig. 273) draw the line *j m*, which would be the half diagonal. This small square, it will be remembered, is a quarter of the larger one, which for the present purpose is sufficient.

Draw diagonals in the surface projected from J H—viz., J H′, J′ H—which will represent the complete diagonals drawn across the square.

Through the point in Fig. 273, where the quadrant passes through the diagonal, draw a line to *n;* and from L in Fig. 272, which is the extremity of the horizontal diameter L L′, set off L N and L N′ equal to *l n* in Fig. 273.

From N and N′ draw lines parallel to A C, and these intersecting the diagonals, will give the points O, O, O, O, corresponding with O in Fig. 272.

Through the intersection of the diagonals draw the perpendicular M M'; then through the points L, O, M, O, L', O, M', O, L, draw the curve which will represent the circular face of the wheel.

Although this form is evidently correct, it is not a pleasant one, since the circle does not seem upright, owing to the longer diameter of the ellipse being on the diagonal drawn at H, instead of on the vertical diameter M' M.

The difference of the results of the different modes of rendering the circle by projection will be clearly understood by referring to the speed-pulley projected from its plan, in lessons in "Projection," and by the circles, etc., projected in "Practical Perspective."

Still the advantages of isometrical projection are so many that the mere appearance is but secondary, as when pictorial views of machinery are required, or views of buildings or blocks of buildings, orthographic projection on the inclined plane, and perspective, can be employed.

Pictures of machines are, however, seldom required for trade purposes, and thus isometrical projection may truly be said to constitute the *perspective of the workshop*.

Proceeding now with our object, project from I K the surface I I' K' K, corresponding with H H' J' J; draw diagonals K I' and K' I, and through their intersection draw the diameters P p and q r.

Now it will be seen that these points P, p, q, r could have been obtained by drawing lines from L, M, L', M', as L P, M r, etc., and this knowledge enables us to find the points s, t, u by simply drawing lines from O, O, O, parallel to A E; these will cut the diagonals in the required points. The same result might be attained by drawing lines from N, N' parallel to A E, to cut K I in V W, and from V W drawing lines parallel to A C, cutting the diagonals K I' and I K'.

To project the square prism penetrating the wheel, set off

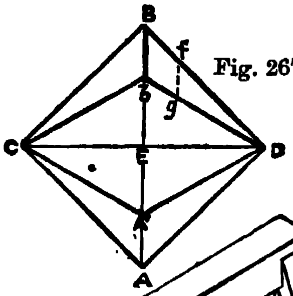


Fig. 267.

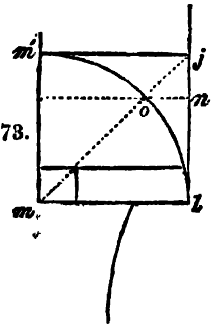


Fig. 273.

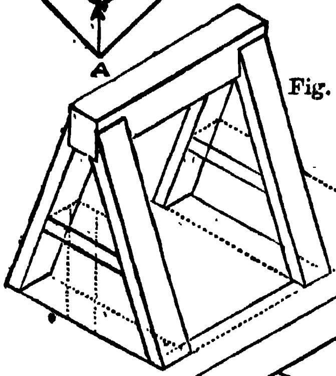


Fig. 274.

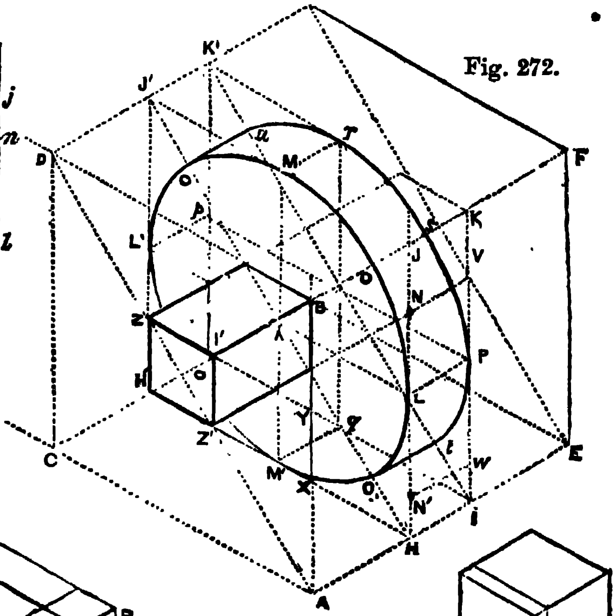


Fig. 272.

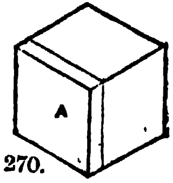


Fig. 270.

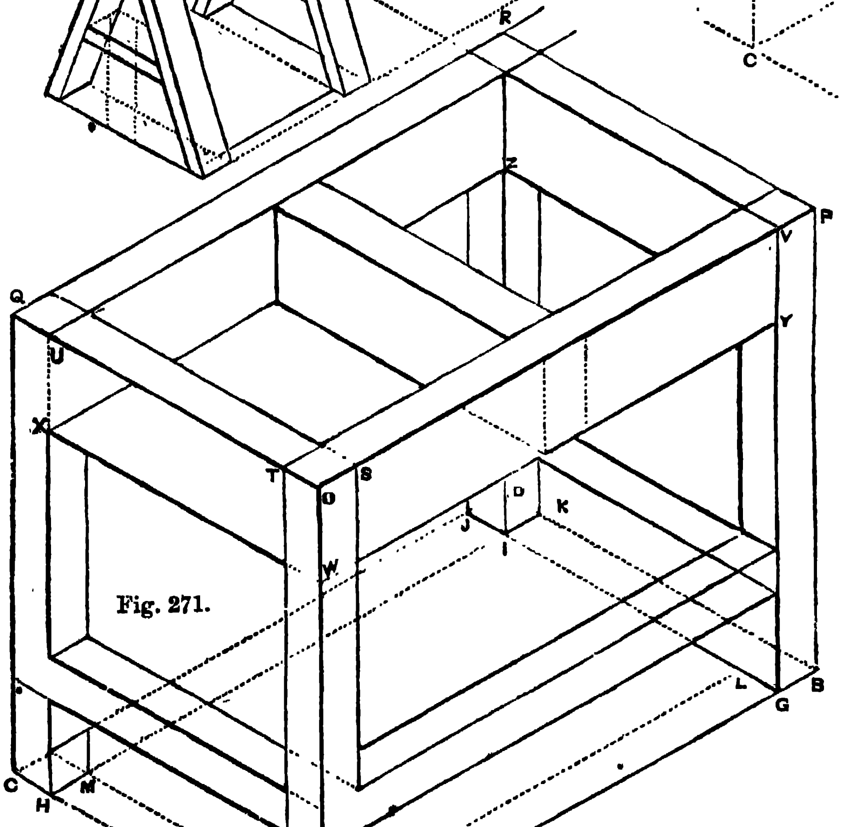


Fig. 271.

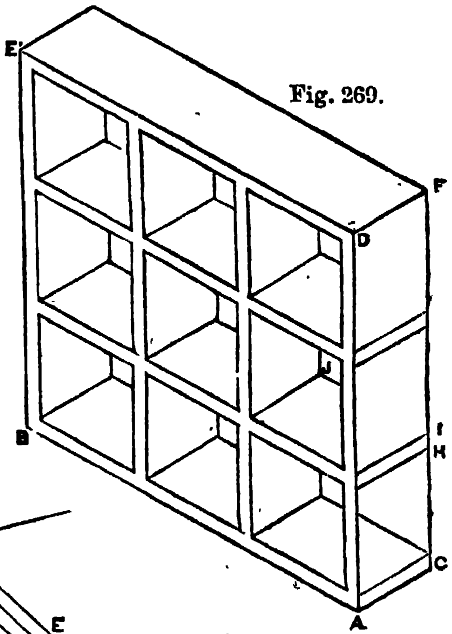


Fig. 269.

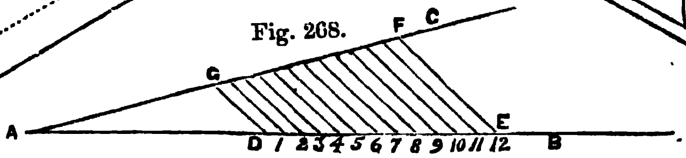


Fig. 268.

its width X Y on A D, and draw lines parallel to A C. These, cutting the diagonals A D, B C, will give the four points I′, Z, Z′, H′, which joined, will be the required projection.

It will be seen that the points I′ and H′ have already been used for a previous purpose. The points now used fall exactly on these; this would be altered if the prism were of a different length.

It will be evident that if the axle were required to be cylindrical, a circle could easily be projected in I′ Z′ H′ Z, as in the former portion of the figure.

The points at which the prism penetrates the wheel are found by drawing lines from I′, Z′, H′. Z parallel to A H, cutting the diagonals J H′, H J′, and its distant end is projected by producing those lines to cut the diagonals of the distant side of the cube.

Fig. 274 is an isometrical projection of a trestle, the working of which, being simply an application of principles already explained, is left to the knowledge and ingenuity of the student.

NOTABLE INVENTIONS AND INVENTORS.

XI.—THE COTTON MANUFACTURE.

BY JOHN TIMBS.

COTTON, named by the Arabs *Kutu* or *Kutun*, is a filamentous matter, produced from the surface of the seeds of the *Gossypium* plants, found wild in both the Old and New World. Herodotus and Arrian speak of the cotton-plant as indigenous in India, and the linen found in Peruvian tombs attests its having existed in that country long before it could possibly have been carried to America by Eastern intercourse. In fact, the wild American cotton-plants are specifically different from those of the Old World; but at the present day, the cotton of the West is cultivated in Asia and Africa, while that of the East has long since been introduced into the American plantations.

Cotton has been wrought into garments for the people of India for 3,000 years. Humboldt states that it formed the only clothing of the natives of Mexico, and is one of the plants they most anciently cultivated. There is evidence of the existence of the cotton-plant in America long before there was any direct communication between the civilised world and the two great portions of that continent; and we have it positively stated that the Spaniards found calico common in the dresses of the inhabitants when they conquered Mexico. It must have been known to the ancient Egyptians, and Rosellini found some of the seeds in one of the monuments of Thebes. It is conjectured that fine Indian cottons were used in ancient Rome because there was a regular commercial intercourse established, through the medium of Egypt, between Rome and India, the chief part of which was on the coast of Malabar, where weaving was practised at the remotest period of which we have any record. Fine cottons were imported into Europe in Juvenal's time, as they were ages before from India; and from China, the country of the Seres, came silk, which the Romans believed to grow on trees. Virgil, in the "Georgics," seems to allude to the cotton-plant and silk as follows:—

> "Of Æthiop's hoary trees and woolly wood,
> Let others tell; and how the Seres spin
> Their fleecy forests in a slender twine."—*Dryden's Translation.*

The Germans, who in general avoid introducing into their language words of foreign origin, call cotton *Baumwolle*, *i.e.* tree-wool. Cotton-wool was known in Spain in the twelfth century. It was imported by the Genoese and Venetians into England and the Netherlands in the beginning of the fourteenth century; but the use to which it was applied, except for candle-wicks, is not known. In 1430 fustians were made, perhaps invented, in Flanders. In 1534, several ships from London and Bristol traded to the Levant, and imported, among other articles, cotton-wool. It might, therefore, be expected that at this time some cotton factories would have been established in England; and this seems to be confirmed by Leland's *Itinerary*, in the reign of Henry VIII., stating that cottons were made at Bolton-le-Moors, in Lancashire, and in the neighbouring villages; also by the mention, in an Act of Parliament passed in 1552 (Edward VI.), of Manchester, Lancashire, and Cheshire cottons.

In the early stages of the trade, the raw cotton manufactured in Great Britain was chiefly the produce of the West Indies; the finer sorts came from Surinam, the Brazils, and the Isle of Bourbon. The cotton from the last-named settlement commanded the highest price in the English market up to the end of the last century, when it was superseded by the Sea Island cotton, found in Georgia, Florida, and South Carolina. The cultivation of cotton in America made very little progress at first. In 1791, sixteen years after the first sample had been sent to England, the total import of American cotton at Liverpool was sixty-four bags. Two years later an American inventor, Mr. Whitney, discovered a very simple and expeditious method of separating the wool of the cotton-plant from the seed—a process which had previously been both tedious and expensive. Yet in 1784, when an American vessel arrived at Liverpool with eight bales of cotton on board, they were seized by the Custom House officers, who had never before seen cotton from that quarter, under the impression that they had been imported from some other country. In 1785 only five bags of American cotton were imported into Liverpool, and in the following year six bags. Such were the small beginnings of that immense trade which now gives employment to millions on both sides of the Atlantic; and which, according to the Abolition party, has been the main cause of the rapid increase of the wealth and influence of the slave power in the United States.

The British colonies are capable of producing vast quantities of cotton, and in our great colony of India the plant is indigenous. It has been computed that a piece of ground of the size of Yorkshire is sufficient to produce a quantity of cotton nearly double the annual consumption of England. The supply from the British possessions is greatly increasing, especially in India, in consequence of the construction of railways and canals; whilst specimens of cotton cloth have been shown from the East and West Indies, and Australia, fully equal in quality to the best from New Orleans. A field of American cotton at the gathering season, when the globes of snowy wool are seen among the glossy dark-green leaves, is singularly beautiful; and in the hottest countries, where the yellow blossom or flower and the ripened fruit are seen at the same time, the beauty of the plantation is still more remarkable. In the early stages of the culture in India it was described as very slovenly, as the seed was sown broadcast, and the plant neglected at every stage of its growth; which, together with the carelessness of the natives in gathering the cotton, in separating it from the seeds, and in packing it, made the Indian cotton very inferior to that of the United States. Nevertheless, the perfection to which the weaving of cotton had then been brought by the natives of many parts of India, notwithstanding their rude and imperfect implements, attests at once their patience and ingenuity. A peculiar combination of heat, light, and moisture is essential to the quality of cotton, the most favourable instance of which may be assumed to be the coast of Georgia and the Carolinas. In 1852 the value of the whole crop of American cotton imported into England was £30,000,000, equal to that of the British wheat crop.

The economy of the cotton manufacture has been exemplified by modern instances, which strikingly carry conviction with them. Thus we read of the superiority obtained by the use of machinery compared with the laborious process of the Hindoo seated on the ground, with his legs in a hole, producing the most beautiful muslin; whereas the cotton can be brought 10,000 miles, cleansed, spun, woven, dried, packed, and carried back again, and then sold in the provinces where it was first grown, at a less price than that of the cloth produced by the Indian weaver. We read also of the early stages of a pound of unmanufactured cotton, which came from the East Indies to London: from London it went to Manchester, where it was manufactured into yarn; from Manchester it was sent to Paisley, where it was woven; it was then sent to Ayrshire, where it was tamboured; it came back to Paisley, where it was veined; afterwards it was sent to Dumbarton, where it was hand-sewed, and again brought to Paisley; whence it was sent to Renfrew to be bleached, and was returned to Paisley; whence it was sent to Glasgow, and was finished; and from Glasgow it was sent per coach to London. The time occupied in bringing this article to market was three years, from its being packed in India till it arrived in cloth at the merchant's warehouse in London. It must have been conveyed 5,000 miles by sea, and about 920 by land, and contributed to support not less than 150 persons, by which the value had been increased 2,000 per cent. Well, indeed, may the steam-engine have been termed "the cotton-spinner's best friend."

The first spinning-machine on record was patented in 1738, by Louis Paul, with whom John Wyatt had connected himself in partnership, though the name of Wyatt appears only as a witness. This statement is founded solely on information furnished by Wyatt's family; and the late Mr. Robert Cole, the solicitor, proved that Louis Paul was the sole inventor of a machine for spinning cotton by rollers, and that Wyatt was a workman in Paul's employ for weekly wages—as proved by patents and papers in Mr. Cole's possession, including several hundred letters, mostly relating to cotton machinery. Paul had already patented a pinking-machine, by which he made considerable profit, and a deed extant proves that he received £200 for allowing one person to use the machine. Paul's spinning-machine patent, as we have said, is dated 1738. It was then requisite for an intending patentee to make an affidavit that he was "the first and sole inventor" of the machine about to be patented, and having obtained the patent he realised considerable sums by granting licences. The deed of May, 1739, is signed by John Wyatt, as attesting witness; and in it the machine is referred to "as invented by the said Louis Paul," who covenants to fit it up. Dr. James, writing to Warren, a Birmingham bookseller, dated London, 17th of July, 1746, says, "Yesterday we called to see Mr. Paul's machine, which gave us entire satisfaction, both in regard to the carding and the spinning. You have nothing to do but to get a purchase for your grant. The sight of the thing is sufficient demonstration enough. I am certain that if Paul could begin with £10,000 he must, or at least might, get more money in twenty years than the city of London is worth." Wyatt had clearly advanced money to Paul at first, and he continued to do so, either as loans or for wages, until the total reached £200. In consequence of this debt, a mortgage deed was prepared between Paul and Wyatt, referring to 300 spindles for spinning, "according to the said invention of the said Louis Paul," which were conveyed to Wyatt, his heirs, etc., to whom Paul covenanted, within six months, to "give the same plan for working, etc., as he hath already gone by." Paul further covenanted to give to Wyatt a plan of another machine which he had invented "for the carding of wool, and other things for the use of the before-mentioned machine, or engine for spinning." Subsequently, when in the Fleet Prison for debt, Wyatt wrote to Sir Leicester Hall, "I am the person that was the principal agent in compiling the spinning engine." Paul obtained a renewal of his patent, and tried to erect one of his machines in the Foundling Hospital, whereby, as he said, "a number of mixed children, between five and fourteen years, might be enabled to earn their food and clothing." Paul's machine was ultimately abandoned, having been brought to no practical effect, although it was adduced many years afterwards as evidence against the originality of Arkwright's invention.

Tracing the means by which astonishing results have been effected, we find that in the year 1760, or soon after, James Hargreaves, an untaught weaver, living near Church, in Lancashire, began to devote his attention to the application of machinery to the preparation and spinning of raw cotton for weft. In the same year the Society of Arts offered a premium for the greatest improvement on the common spinning-wheel, and afterwards offered a premium of £100 for the construction of a machine that would spin six threads of wool, cotton, flax, or silk, at the same time. Hargreaves first invented an improved method of carding the cotton, not very different from that now in use; and in 1767 he invented the spinning-jenny, drawing several threads at once—at first containing eight spindles—made to revolve by bands from a horizontal wheel. The power of the spinning-jenny was soon increased to eighty spindles, when the saving of labour produced such alarm amongst those persons employed in the old mode of spinning, that a party of them broke into Hargreaves' house, and destroyed his machine. It was, however, again brought into use, when a second rising took place, and both carding and spinning machines were destroyed, one result of which was that the manufacture was, for a time, driven away from Lancashire to Nottingham. Hargreaves stated that he derived his idea of the jenny from seeing a hand-wheel with a single spindle overturned, when he remarked that the spindle, which was before horizontal, was then vertical; and as it continued to revolve he drew the roving of wool towards him into a thread. He then conceived that if something could be applied to hold the rovings as the finger and thumb did, and that contrivance to travel backwards on wheels, six or eight, or even twelve threads, from as many spindles, might be spun at once. This was done, and succeeded; but Hargreaves, driven by the mob, as we have described, to Nottingham, could not bear up against such ill-treatment, and there died in obscurity and distress. He had previously given the property of his machine to the Strutts, who thereon laid the foundation of their industrial success and opulence and a peerage.

The cotton yarn produced by the common spinning-wheel and spinning-jenny could not, however, produce cotton yarn sufficiently strong to be used as warp, for which purpose linen yarn was employed; and then another machine, the spinning-jenny, which took up what Hargreaves had begun, was invented by as humble an individual, Richard Arkwright, who was born at Preston in 1732, and being the youngest of a poor family of thirteen children, he received very little education. He was bred to the business of a barber, which he carried on in the town of Bolton, where remain two shops once occupied by him. He became a dealer in hair, which he collected through the country, and having dressed it, he sold it to the wig-makers. He possessed likewise a profitable secret method of dyeing hair.

Up to this time the English cotton cloths (called *calico*, from Calicut, in India, the place of their production) had only the weft of cotton, the warp or longitudinal threads being of linen, it being impossible by any means then known to spin cotton with a sufficiently hard twist to be used as a warp. The raw materials were delivered by the master to cottagers living in the villages of the district, who both carded and spun the cotton, and wove the cloth. The demand for these cottons soon became so great, that although there were 50,000 spindles constantly at work in Lancashire alone, each occupying an individual spinner, they could not supply the quantity of thread required. To remedy this state of things, several ingenious individuals had thought of spinning by machinery, instead of by the one-thread wheel. Among these was Paul, whose machines have been described. A Mr. Robert Earnshaw, of Mottram, in Cheshire, in 1753 invented a machine to spin and weave cotton at one operation, which he showed to his neighbours and then destroyed, through the generous apprehension that he might deprive the poor of bread.

Arkwright had now turned his attention to mechanics, and with one Kay, a clockmaker, who made him some wheels, they jointly devised a model of a machine for spinning cotton-threads; and next year, 1768, they erected this machine at Preston, in the parlour of the house adjoining the Free Grammar School; but dreading the hostility of the Lancashire people to their attempt to introduce spinning by machinery, they removed to Nottingham. Here wanting capital, Arkwright took his model to Messrs. Need and Strutt, stocking-weavers at Nottingham: Mr. Strutt being a man of scientific attainments, was satisfied of the nature of the proposed machine, and he and his partner joined Arkwright in 1769, and took out a patent for the machine as its inventor. It is related that when Arkwright applied to Mr. Strutt, his machine was much impeded by the fibres of the wool sticking to the roller, which defect Mr. Strutt engaged to remove on condition of participating in the profits of the result. They repaired to the mill, when Mr. Strutt, taking a lump of chalk out of his pocket, applied it to the roller, and the sticking was instantly prevented. A spinning-mill driven by horse-power was, at the same time, erected and filled with frames. In 1771 Arkwright and his partners established another mill at Cromford, in Derbyshire, the machinery to which was set in motion by a water-wheel; and in 1775 he took out a second patent, with additions to his former one. This was a combination of the carding and spinning machinery with two pairs of rollers, the one revolving faster than the other, which forms the peculiarity of the machine.

The most important of Arkwright's contrivances was his drawing out the cotton to a harder twisted thread, so as to be used for warp as well as weft. This was managed by a principle altogether novel. The cotton was first drawn from off the skewers by one pair of rollers made to move at a comparatively slow rate, and which formed it into threads of a first or coarser quality; but at a little distance behind the first was placed a second pair of rollers—revolving three, four, or five times as fast—which took it up when it had passed through the others, the effect of which was to reduce the thread to a degree of fineness so many times greater than that which it originally had. The first pair of rollers might be regarded as the feeders of the second, which could receive no more than the others sent to them, and that again could be no more than these others themselves took up from the skewers. As the second pair of rollers, therefore, revolved, we will say five times for every revolution of the first pair—or, which is the same thing, required for their consumption in a given time five times the length of thread that the first did—they could obviously obtain so much length by drawing out the common portion of cotton into thread of five times the original fineness. Nothing could be more beautiful or more effective than this contrivance, which, with an additional provision for giving the proper twist to the thread, constitutes the *water-frame*, or *throstle*, so called from its being originally moved by water-power. Such, in principle, were the two great inventions that effected an entire change in the manufacture of cotton, wool, and flax.

The idea of spinning by rollers Arkwright accidentally derived from seeing a red-hot bar elongated by being made to pass between two rollers; and though there is no mechanical analogy between that operation and the process of spinning, it is not difficult to imagine that by reflecting upon it, and placing the subject in different points of view, Arkwright might be led to this invention, which he specially claimed as his own. Of other machines which he included in his patents, he was rather the improver than the inventor; and the original spinning-machine for coarse thread, the spinning-jenny, Arkwright admitted to have been first conceived by Hargreaves. Previous to this time no establishment of a similar nature had existed, none at least to which the same system of management was applicable, and it strongly marks the judgment and mental powers of Arkwright, that although the details of manufacturing or commercial business were altogether new to him, he at once introduced a system into his works which has since been universally adopted by others, and which, in all its main features, has remained unaltered to the present time. In the year 1775 he completed a series of machinery so various and complicated, yet so admirably combined and well adapted to produce the intended effect in its most perfect form, as to excite the astonishment and admiration of every one capable of appreciating the ingenuity displayed and the difficulties overcome. At the expiration of the partnership of Strutt and Arkwright they separated. Arkwright went on by himself at Cromford, and the Strutts for themselves at Belper. A fierce spirit of detraction strangely represented that Arkwright stole the invention of another; but Mr. William Strutt, who was a competent judge on such subjects, attested that Arkwright was a skilled mechanic, and quite equal to such an invention. He did not, however, enjoy the rights of his ingenuity without opposition alike from the manufacturers, and the spinners, and the weavers. His factories were attacked, his patents were invaded, and the merit of his being an original inventor denied. Circumstantial accounts of this system of injustice are to be found in the histories of the cotton manufacture, but cannot be quoted in this sketch. The "Encyclopædia Britannica" has this conclusion: "We have access to know that some of Mr. Arkwright's most intimate friends never had the slightest doubt as to the originality of his inventions, and some could speak from their own personal knowledge, and their testimony was uniform and consistent," and such became the opinion of the principal manufacturers of Manchester. "If," says the "Penny Cyclopædia," "the evidence be fully weighed upon which it has been attempted to convict Arkwright of the serious charge of pirating other men's ideas, we think it will rest upon very slight grounds, while the proofs which he exhibited of possessing talents of the very highest order in the management of the vast concerns in which he was afterwards engaged, are unquestionable." It was not, however, until after the lapse of five years from their erection, that from the works at Cromford any profit was realised; but from that time wealth flowed in abundantly. The establishments were greatly extended, and new ones were formed, and success continued to flow, notwithstanding Arkwright's patent had been cancelled by law. Meanwhile, he had almost built the town of Cromford, and lived in patriarchal prosperity amidst the scenes of industry where he raised up his own fortune. He served as High Sheriff of Derbyshire in 1786, and received knighthood from King George III. But his health failed, and he died in 1792, in the sixtieth year of his age, leaving a fortune little short of half a million, besides having presented each of his ten children with £20,000. No man ever better deserved this good fortune, or had a stronger claim on the respect and gratitude of prosperity. His inventions opened a new and boundless field of employment, and while they have conferred infinitely more benefit on his native country than she could have derived from the absolute dominions of Mexico and Peru, they have been *universally* productive of wealth and enjoyment.

The power which gave motion to the rollers and spindles of Arkwright and his fellow-inventors was supplied at first by falls of water, when manufacturers of necessity planted their establishments in districts where water-power was readily obtained, however inconvenient those situations might be in other respects. Watt's improvements in the steam-engine, however, supplied them with what they wanted, at a higher price certainly, but at any place and at any time they chose. As soon as steam-engines were used to drive the machinery, factories might be set up in towns, made independent of drought or flood, and wrought by a motive power whose energies could be adapted with the utmost nicety to the work required. Steam-engines were accordingly employed in turning the rollers and other machines used in spinning the cotton, as early as 1785, and the inventions of Watt and Arkwright, when thus combined, gave an impulse to the manufacture, which neither of them by itself could have produced. To show the advantages that have resulted from this combination of intellect, industry, and capital, it may be said that the quantity of cotton introduced into this country was under 5,000,000 pounds when the inventions of Arkwright were projected; in 1868 it was 11,857,893 cwt.

CIVIL ENGINEERING.—VI

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS (*continued*).

The loss of water in a canal is variable, and at some periods excessive. We have already pointed out the necessity of providing for this loss by effecting a communication between the summit level of the canal and some invariable source of supply. This point is of paramount importance, and demands a still closer notice. Supposing the supply to be drawn from a river, it is usual to construct a weir across it, and after damming up the stream, to admit a portion into the canal. Thus whilst the level of that portion of the river above the weir will vary very slightly under the influence of drought or rainfall, the amount admitted into the canal will be proportionally constant. Under all circumstances of supply, however, it is imperative to provide a carefully constructed outlet for any excess of water arising from floods; the position of this outlet will, of course, be in the same section of the canal with the supply. The *character* of the water admitted to the canal is a matter of importance. If derived from a turbid source it should, if practicable, be passed through filtering beds, or reservoirs, in which any suspended matter may be allowed to settle. This plan will permit of a much longer period elapsing before the water need be drawn off the canal for cleansing the channel, for under all circumstances an accumulation or deposit of mud in the bed will arise, and unless a system of *sluicing*—a plan adopted to a great extent in Italy—be employed, the water must be occasionally drawn off; and as from necessity all navigation has to be stopped during this period, every means should be adopted to obtain *pure* water to supply the loss.

The course of the canal, which we have stated must be guided by commercial as well as engineering considerations, needs a few words of consideration. It is not always possible, owing to the nature of the ground, to lead the main channel of a canal through a town. If such is the case, an offshoot or branch leading to some convenient locality in the town, and terminating with a wharf, must be constructed.

A certain proportion must be allowed to exist between the *size of the locks* and the *interval between* them. The reason for this is that a lock full of water drawn off from any interval above it for the purposes of navigation shall not lower the water in that interval excessively, that is, so that a loaded barge could not float. As a matter of course, the dimensions of the channel of a canal are in terms of the barges which navigate it. Thus if we suppose the maximum draught of any boat = D, its extreme breadth = B, and its extreme length, including the rudder, = L, it is usual to allow the depth of water (D′) to be D + 1·5 feet, in which D usually equals 5 feet; the width at the surface is usually $3(B + 3D') = 40$ feet; and the width of the bottom $3B = 25$ foot. The width of the channel becomes greatly narrowed as it approaches the lock, where the width is the least. A lock need never exceed the breadth of a barge by more than 1 foot or B + 1 foot. Again, the length of the lock should not exceed L + 1 foot, and the depth D + 1½ feet. An ordinary canal lock is 75 feet long, 8 feet broad, and 5 feet in depth over the mitre-sill. Now the *least* length allowable between locks should be such that 12 inches of depth over and above what a loaded barge will draw shall, when the barge is enclosed in the lock and the water drawn off, never lower the water in the interval above more than 6 inches. Hence when the chambers of the lock are large and the canal narrow, a greater distance must be arranged between the locks.

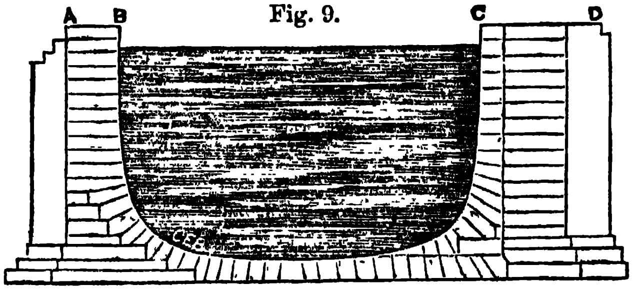


Fig. 9.

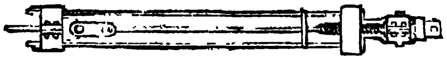


Fig. 12.

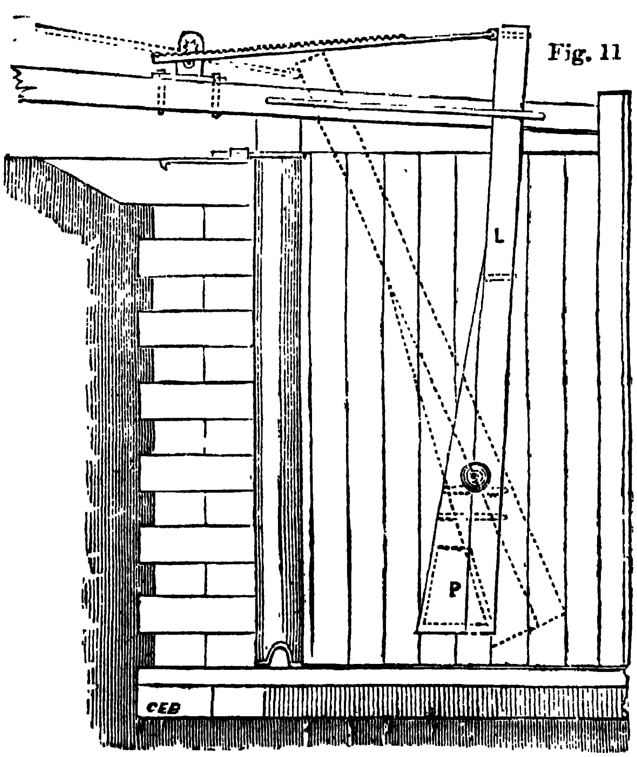


Fig. 11

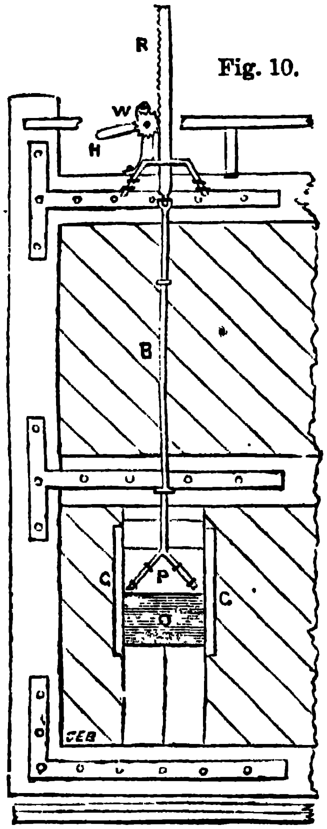


Fig. 10.

The Saone and the Loire are united by the canal of Briare, navigable to ships of small burden; hence the respective dimensions are larger than those given above. The locks are 110 feet long and 17 feet wide, giving a superficial area of 1,870 feet. If the fall be 6 feet 4 inches, 11,843 cubic feet will be drawn from the upper section; if 8 feet 6 inches, 15,859 cubic feet; if 10 feet 6 inches, 19,635 cubic feet. The canal being 48 feet wide at 3 feet below the ordinary level of the water, the length of the interval to the next lock should be 446 feet, so that the fall of 6 feet 4 inches in the lock should not lower the water in the interval more than 6 inches. It must, however, be 607 feet when the locks are 8 feet 6 inches of fall, and 755 feet when the fall is 10 feet 6 inches.

The importance of attending to these points will be seen from supposing a case where the reverse has occurred from necessity or oversight. If two locks, having a fall of 8 feet 6 inches, were only separated by 160 feet, the water drawn from the interval for the purpose of mounting the boat would lower it nearly 26 inches, and there would not remain sufficient to keep it afloat; consequently it would be necessary to draw a lockfull from the upper interval, and then a second to cause it to rise, whilst only one would be required if the locks were at a sufficient distance. In many instances canals have been cut to connect two tidal rivers. There is in such a case no difficulty in obtaining the water for the navigation, as the whole channel may be re-filled at every tide up to the level of that tide. In this case, however, the entire channel must have a much larger capacity, as compared with that of the locks, than is required in other cases, because, as the supply is only obtainable at stated intervals, sufficient must be admitted at these periods to compensate for the whole loss arising from the navigation during the interval. Hence the canal becomes its own reservoir.

The form of the chambers of locks should be a parallelogram; it is the most convenient, and expends the least quantity of water. In the canal of Languedoc the form is oval, but the greater loss of water expended more than counterbalances the advantage of greater strength obtained by the curved wall. The walls of a lock should not be perpendicular outside. The pressure of water being proportionate to the height of the column, the walls must have the greatest width at their base, and narrow gradually towards their summit. Inside, the wall may be perpendicular, except at the bottom, where they may have the same curve as the sides of the boats. The walls should not be less than 4 feet 3 inches thick at the level of the water, and should have throughout them a lining of bricks set in cement to prevent filtration of the water. The openings of the lock are gradually widened, after leaving the mitre-sills, by what are termed *shoulders of defence* facing the higher level, and *discharging walls* facing the lower level. The continuations of these are termed *wing walls* and *return walls*. The whole of these are built of one continuous piece of masonry upon each side of the lock respectively, and have for their object the prevention of the water passing round and behind the chamber-walls, and the resistance necessary to withstand the thrust of the gates when under the influence of the water-pressure. In Fig. 9 we give an elevation of the usual form of a lock-chamber contiguous to the gate. The finished masonry extends from A to D, from which points the shoulders spring, diverging right and left. The position of the anchors which support the collars or hanging-pieces of the gates, as shown at Fig. 7 (Vol. I., page 386), is allowed for during the building of the side walls by the insertion of solid blocks of stone. The platform of the lock is a point requiring great care in construction. It has to receive the shock of the water when admitted by the opening of the sluice, and is very difficult to keep in repair. It is usually formed of timber laid upon a foundation of piles, with a layer of masonry beneath it. The ends may with advantage be worked into the masonry of the side walls. Where it is possible to obtain them, large flagstones are preferable for the surface of the platform.

The timbers forming the gates of locks will vary in size according to the dimensions of the opening, and their respective depths below the water-level, the lower rails having to support a greater pressure than those above. The weight of water supported by each horizontal rail will be found by multiplying their length, the interval from one to the other (usually 38 inches from centre to centre), the height of the water above the centre of the rail, and the product by 62 lb. (the weight of a cubic foot of water), the last product of these measures giving the number of pounds which the rails ought to support throughout their whole length.* For small gates the timbers or rails may be from 4 to 5 inches square, and for larger, from 7 to 8 inches; the latter being sufficient for a fall of 10 ft. 6 in., with a width of 17 feet between the hanging posts, six rails being put in the height. Whilst on the one hand it is desirable to have an excess of strength above the calculated requirement, it is on the other hand undesirable to make this excess excessive, as so much more weight is injurious to the supporting collar and the masonry to which it is attached. The diagonal direction of the braces may be dispensed with by the substitution of a bar of iron placed diagonally from the supporting collar to the lower end of the shutting-post. The escape of water through the gates must in every way be guarded against. It is very difficult, indeed almost impossible, to prevent its escape through the joint of the shutting-posts, because of the difficulty of making them touch throughout their own length. To obviate this they should be cut in a circular form, one concave and one convex; the curvature should be with a radius of about 12 feet. The rails are mortised into the uprights, and are further strengthened by strong angle irons and T-pieces.

The sluice is ordinarily an opening, O (Fig. 10), left in the framing of the gate, and closed by a paddle, P, working vertically in guides G, G, and raised or lowered by an iron bar, B, terminating at the top in a rack, R, actuated by a pinion, W, and handle, H.

In Fig. 11 is shown another kind of sluice, in which the paddle, P, moves laterally, being fixed to the short end of a lever, L, heavily weighted at the lower or paddle end. The movement is given by a rack and pinion working nearly horizontally. The idea of this arrangement is that when no water is pressing against the paddle, the weight at the bottom draws it over the aperture, and when drawn back by the toothed gear it will remain back until the water-pressure ceases through a level having been obtained. In some cases screws are employed to raise the paddles (Fig. 12). This plan is adopted at Dunkirk. There are, as we have intimated in a former chapter, other modes of raising or lowering the barges from one level to another besides locks. The "lift" is a plan adopted upon the *Grand Western Canal*, and has certain advantages over the lock. These lifts are 46 feet high, and consist of two chambers, having a piece of masonry between them. Each chamber contains a timber cradle, in which the boat is placed which requires to be raised or lowered. When on a level with the canal the cradle allows the boat to swim into it by raising a water-tight gate at the end. The two cradles, when full of water, or when containing a boat, balance each other, being suspended by strong chains, which pass over iron wheels placed above the level. An additional 2 inches of water in the cradle not containing a barge is sufficient to raise the barge in the other. The barges using these lifts weigh 8 tons, and occupy 3 minutes in passing up or down the 46 feet, and only 2 tons of water are consumed in the operation, whereas 3 tons would be expended for boats of this tonnage in the ordinary way. If an inclined plane is employed to raise or lower the boats, they are floated upon a sledge, which is drawn up by a steam-engine.

Notwithstanding the obvious advantages of conveying heavy merchandise by water, it is remarkable that scarcely any attention was paid to the subject in this country until about the middle of the sixteenth century, when it was proposed to render the Isis and the Avon navigable, and then to unite the two streams by a canal 3 miles long. The first canal of importance was the Duke of Bridgewater's, between Worsley and Manchester, executed by Brindley. Several remarkable instances of bold and successful engineering occur upon this canal, especially the aqueduct over the Irwell at Barton, consisting of three semi-circular arches, the centre arch being 63 feet span and 39 feet over the river. Since the year 1776 no less than 2,400 miles of canal have been made in Great Britain. One of the most celebrated is the *Caledonian Canal*, uniting Fort William with Inverness. The entire distance between these points is upwards of 100 miles, but in consequence of the natural position of the chain of Lochs Ness, Oich, Lochy, Eil, and Linnhe running in an almost right line in a direction from north-east to south-west, only 21 miles of canal were requisite to render the entire line navigable for vessels drawing 15 feet. The breadth of the canal and enlargements of the locks is 122 feet at top, and 50 feet at bottom, and the depth 20 feet. The slope of the sides is as 2 of height to 3 of breadth, and is continued to within 2 feet of the water-level, the bank being 6 feet wide. Throughout the entire canal there are 23 locks, each being 40 feet wide and 172 feet long. Somewhat to the south of the northern entrance an enlargement of the canal to 162 yards of breadth for 967 yards of length constitutes a floating dock for repairs and other purposes of 32 acres. Loch Ness, the most northernly of the chain, has a level 32 feet above the canal, to which vessels are raised by the four Muirtown locks, each 180 feet long, and 40 feet broad. The addition of Loch Ness gives at once a natural addition of 22 miles to the navigation. At its south-west extremity five more locks raise the navigation 40 feet higher to Loch Oich. The waters of Loch Lochy are 10 feet higher than those of Loch Oich, and are reached by the intervention of a single lock. This loch forms the summit of the canal, which then descends 64 feet to Loch Eil by eight locks. The whole of these eight connected locks are formed of solid masonry 1,500 feet long. The foundations of the embankment at Clachnacharry are in mud, which is so soft that an iron rod could be thrust down 55 feet with ease. The mode in which the lock at this point was constructed is so instructive that we give it. The immense depth of mud precluded the use of a coffer-dam; an iron railway was accordingly laid down, on which the heavy clay found close by was carted, and the two banks of the canal were formed by "tipping" as far as where the depth of water at an ordinary neap tide was 20 feet, and when the site of the intended lock was approached, the banks were united into one mass. The weight of the clay compressed the soft mud, and squeezed out the water. Upon this mound of clay a quantity of stone was laid, and allowed to remain for six months, by which time the mound had sunk 11 feet, and become consolidated. The pit for the lock was then excavated out of the consolidated clay, and the water kept down by a steam-engine of nine-horse power. At the bottom of the excavation rubble stone masonry was laid with hydraulic mortar to the thickness of 2 feet in the middle of the chamber, increasing to 5 feet on each side, and upon this an inverted arch of masonry was struck, and the side walls built. The entire cost of the canal was £982,359, and the quantity of Baltic timber expended upon the works was so great that the price rose from 2s. 6d. to 7s. per cubic foot during the time occupied in its construction.

THE ELECTRIC TELEGRAPH.—VIII.

THE MORSE PRINTING TELEGRAPH—RINGING-KEY—CODE—THE RECEIVING INSTRUMENT—ARRANGEMENT OF INSTRUMENT-ROOM.

The telegraph instruments we have already described are those that transmit their signals by the property which the electric current possesses of reversing the poles of a magnetised needle. We must now consider the next class of instruments—namely, those in which the power of the current to convert a bar of soft iron into a temporary magnet is turned to account. As we saw in our lessons in "Electricity" in The Popular Educator, we have only to take a rod of iron, and wind some insulated wire many times round it, and then, by sending a current along the wire, we at once convert the rod into a powerful magnet. This magnetic power continues as long as the current passes, but ceases as soon as it is in any way interrupted. Now it is pretty clear that we may in several ways avail ourselves of this power in the transmission of messages, since it is perfectly immaterial at what part of the circuit the current is interrupted.

The telegraph instrument which, next to the needle instrument, has come into most general use, is one of this class, and is known as the "Morse Instrument," after Professor Morse, by whom it was invented. This instrument is found in practice to answer extremely well; it may, in fact, be in most respects regarded as the best instrument known for general use, being simple in its construction and action, and not liable easily to get out of order. One great advantage that it possesses over the needle instrument is that it prints or embosses its own message on a strip of paper, and thus leaves a permanent record; whereas, in those already described, the operator must observe the very transient signals, and at once write them down or dictate them to another clerk. If a word or letter be dropped, the sender must be interrupted and made to repeat; while in the Morse the whole message is printed, and the receiving clerk can then carefully read and transcribe it at leisure. The original strip may also be preserved for reference if necessary; and, in addition to this, the fact that the transmitting clerk knows that he is actually printing his message, and that thus any mistake will at once be brought home to him, tends to render him much more careful.

The peculiar click of this instrument will be familiar to many travellers, as it may very frequently be heard at work in the booking offices of railway stations.

The "transmitter," or, as it is usually called, the "ringing-key," of this instrument is much simpler in its construction than that required for a needle instrument, since the current has only to be sent in one direction. All that is required is an arrangement by which the circuit can be interrupted, and a battery current made to pass along it at pleasure.

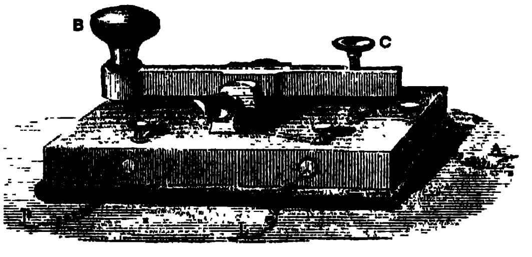


Fig. 34.

All this is easily effected by the instrument shown in Fig. 34. The base is made of some hard, dry wood, usually mahogany, and a stout brass rod is mounted on an axle fixed to this; a handle, B, being affixed to one end of it, and an adjusting screw, C, to the other. One battery wire, P, is connected to a binding-screw, which communicates with a small anvil placed under D, and is usually tipped with platinum; the other battery wire is joined to the earth-plate. L is the line-wire, which it will be observed communicates through a binding-screw with the rod B C.

Above the small anvil is a short piece of wire which comes into contact with it when B is pressed down, and thus causes the current to pass from P to L, and on to the distant station. A spring, however, keeps this point away from the anvil when the instrument is at rest.

The screw C presses on another plate or anvil at the other end, from which a wire, A, leads to the receiving apparatus and on to earth. The reason of this is that the wire L is used for the transmission of messages in either direction. When, therefore, the key is at rest, as shown, any current arriving by L passes through C and A to the receiving portion of the apparatus, and there makes the required signals. When, however, we want to send a message, and press down the key for that purpose, our own receiver is cut out of circuit, and the current only goes through the distant instrument.

One inconvenience sometimes arises from this arrangement. If the line-wire were in any place broken or injured, no current would pass, and the operator might continue to send the message, supposing all was right, for as the current does not pass through his own instrument, he would not know that the circuit was broken. The receiver, too, might want to interrupt him, but with this arrangement would be unable to do so. A small galvanometer is therefore always placed in the course of the line-wire, and the constant currents sent cause the needle of this to keep continually oscillating. If now the distant operator wishes to interrupt, he merely presses down his key, so as to remove the screw C from its anvil, and thus break the circuit. No current will now pass, and the sender, perceiving that his galvanometer has ceased to vibrate, will at once wait and hear what the distant station has to say. It will thus be seen that this small galvanometer is a very important part of the apparatus.

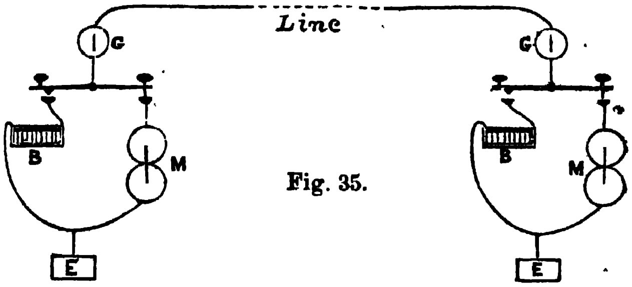


Fig. 35.

The sketch in Fig. 35 will render clear the manner in which the different pieces of apparatus are joined in circuit in the way we have been explaining. For the sake of simplicity, we have here represented the key as consisting of a bar of metal, the centre of which is in connection with the line-wire, while the ends may communicate with the battery, B, or the instrument, M; and by referring to the illustration of key already given, it will be seen that this is essentially the case. G, G represent the galvanometers placed in the circuit of the line-wire, and E, E the earth-plates.

The receiving part of the instrument is much more complicated in its construction. The message is printed on a strip of paper about half an inch wide, a long roll of which is placed on a drum supported above the body of the instrument. The end of this riband passes between two rollers, which are set in motion by means of clockwork, the driving power being in some cases derived from a spring contained within a barrel, and in other cases from a weight. A fan is attached to some portion of the clockwork, so as to render the motion of the paper uniform. This part of the apparatus does not require further description here, and almost every maker adopts some special form of construction peculiar to himself.

The electrical portion of the instrument is that which more especially concerns us, and this is remarkably simple in its make and action. The line-wire is connected to a binding-screw attached to the base of the instrument, and from this the current passes round the coils which surround two iron rods placed side by side. In Fig. 36 we have a view of the essential parts of the apparatus A is one pole of the electro-magnet, and B its keeper, which is fastened to the lever B D. This oscillates with very little friction on pivots at C, and its play is limited by the arm, I, attached to it, and the set-screws, G G. The end of A is usually covered with a piece of thin paper or a layer of varnish, as otherwise a little magnetism often remains in it, causing the keeper B to remain in contact after the current has ceased. A spiral spring, capable of adjustment by the milled head H, is fastened to the end of the lever remote from the magnet, and when the current is not passing holds the keeper as far away from the magnet as the set-screws, G G, will allow. D is the style, or pen, and is so placed that it is opposite a groove in the roller E. The paper riband is drawn between E and F

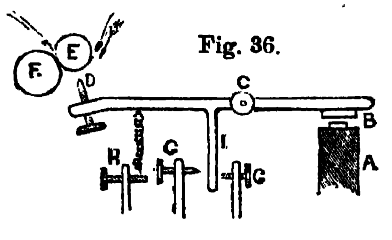


Fig. 36.

As soon now as a current is transmitted along the line-wire, and passes round A, it converts it into a magnet, and overcoming the spring at H, presses the style D against the roller, and thus embosses or indents the paper strip.

If this strip be in motion we shall evidently have a continuous line traced along it so long as the current passes, and when we interrupt the current there will be a corresponding blank. We might in this way send strokes of various lengths, but this would be found inconvenient, since the paper does not always travel at exactly the same rate. Only two signs, therefore, are employed—a dot, which is produced by sending a very brief current, and a dash, which is made by keeping the key pressed down for an instant.

Sometimes, instead of a blunt point at D, we have a wheel with a narrow edge, which is in contact at one side with an ink roller. In this way the marks are inked on the paper strip, instead of being embossed.

We have, then, here, as in the case of the needle instrument, two distinct signs—the dot and the dash—and by a judicious combination of these we can send any letter in the alphabet we choose. The very same code is employed as that used with the single-needle instrument; in fact, the code used for that is merely the Morse code translated, an inclination of the needle to the left being considered the equivalent of a dot, and one to the right representing the dash. We append, however, the full code of the Morse, which is now adopted in nearly all countries. The letters of the alphabet are thus represented:—

A ·—
Ä (æ) ·—·—
B —···
C —·—·
D —··
E ·
F ··—·
G ——·
H ····
I ··

J ·———
K —·—
L ·—··
M ——
N —·
O ———
Ö (œ) ———·
P ·——·
Q ——·—
R ·—·

S ···
T —
U ··—
Ü (ue) ··——
V ···—
W ·——
X —··—
Y —·——
Z ——··
Ch ————

The following code is adopted to represent figures:—

1 ·————
2 ··———
3 ···——
4 ····—
5 ·····

6 —····
7 ——···
8 ———··
9 ————·
0 —————

In this code, as will be seen, no letter requires more than four signs, while figures are all represented by five. The stops can easily be learnt from the needle-code in Lesson V. Spaces about equivalent in length to the dash are left between each letter, those separating the words are about three times as great. We give as an example a specimen of a strip as received, the equivalent letters being placed under each sign.

—·—· ·— ··· ··· · ·—·· ·—·· ·—·—·— ···
C A S S E L L ' S

— · —·—· ···· —· ·· —·—· ·— —··
T E C H N I C A L

· —·· ··— —·—· ·— — ——— ·—· ······
E D U C A T O R .

The main difficulty in transmitting messages with this instrument is found in arranging the spaces properly; and to meet this Professor Morse introduced a transmitting plate, in which each letter was represented by strips of ivory and brass inlaid in a board. Any letter could then be sent by merely drawing a metal style connected with the line-wire over the sign on the plate, but this never came into general use. The full construction of the receiving apparatus, and the general arrangement of the instruments in the office, will easily be understood by reference to Fig. 37, which shows the interior of an instrument-room completely fitted.

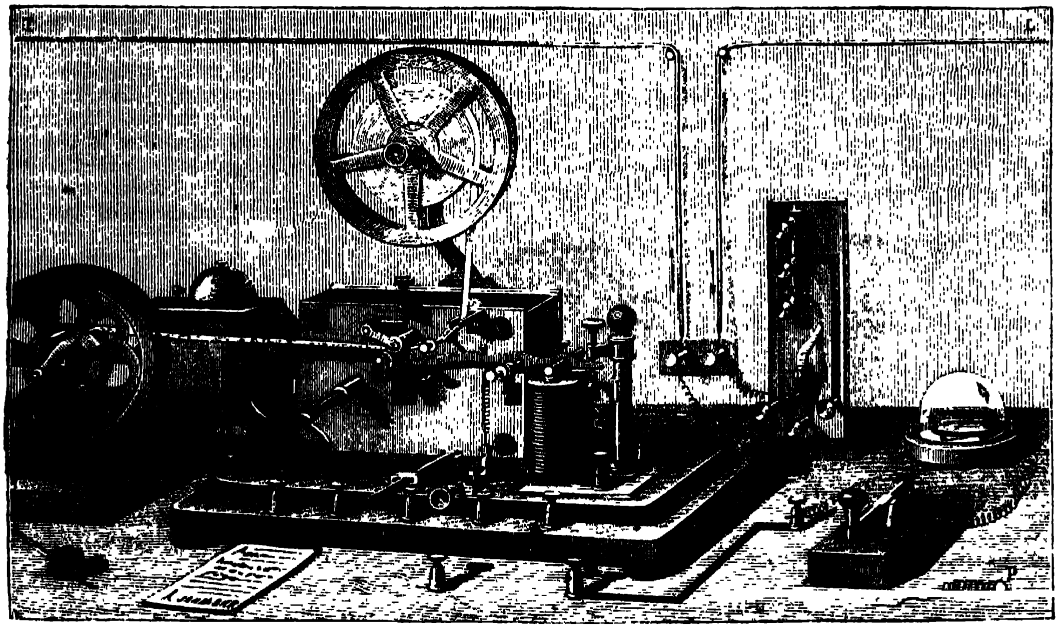


Fig. 37.—INTERIOR OF AN INSTRUMENT-ROOM.

In the instrument here shown, the set-screws which govern the play of the lever are placed at the end of the lever instead of on an arm attached to it, as seen in Fig. 36, but they act in the same way. The course of the paper strip can now be traced as it leaves the upper drum, passes between the rollers, and, after being embossed, is wound on to the second drum to the left. Both these are so made that one side will take off, and allow the disc of riband to be removed or replaced. The clockwork is contained within the brass case of the instrument, the key by which it is wound up being seen.

P is the battery-wire just disconnected from the ringing-key, behind which is the galvanometer. To the left of this is a switch, by which the current as it enters may be directed at pleasure to the alarum or the instrument, or, in the case of an intermediate station, be made to pass straight on. The wire L is that which communicates with the line, while T is connected to the earth-plate. The alarum is seen behind the drum on which the riband is coiled.

The only other point to which we need refer is the small lever seen at the base of the receiving instrument: by means of this the clockwork can be started or stopped at pleasure. It would not do for the paper to be continually unwinding; the clockwork is therefore stopped by means of this lever. As soon as the alarum rings to indicate that a message is coming, the clerk alters the switch, so as to direct the current to the instrument. He then gives a signal to show he is attending, and starts the clockwork. The riband then commences to unwind, and is embossed with the message which he can afterwards transcribe.

THE STEAM-ENGINE.—VIII.

By J. M. Wigner, B.A.

CONDENSER—AIR-PUMP—FORCE-PUMP—GOVERNOR BALLS—THROTTLE-VALVE—HORSE-POWER—WATT'S INDICATOR.

In non-condensing engines the steam, after having done duty in raising or depressing the piston, is allowed to escape by the exhaust direct into the air. The consequence of this is that the full pressure of the air is exerted against the opposite side of the piston to that on which the steam is acting, and all this pressure has to be overcome before the piston can be moved. In the condensing engine which we are now describing this source of waste is almost obviated. The cylinder here is nearly void of air, so that if we can in any way condense the steam that fills the cylinder after it has accomplished its work in driving the piston to the end, we shall have a vacuum into which the piston may return, and shall thus avoid all loss of power from this cause. This object is accomplished by means of the condenser, which is another of the many great improvements in the engine that are due to the genius of James Watt.

In the earliest engines the plan adopted was to cool the cylinder by the application of cold water to its exterior surface. This plan was very slow, and caused a great loss of heat, as the cylinder became so cold that a portion of the fresh steam as it entered was expended in raising its temperature again, and in so doing became condensed on its inner surface.

The next improvement consisted in injecting a jet of water into the cylinder, and in this way the condensation was effected much more rapidly, but still there was much waste of heat.

At last Watt introduced the separate condenser, which has been found to answer remarkably well, and to effect a very great saving. The condenser is represented at O (see Fig. 32, page 17), and consists of a large air-tight vessel communicating with the exhaust by means of the pipe seen under the valve facing.

A small force-pump, R, worked by a rod, H, jointed to the working beam, raises cold water from a cistern or well, and forces it along the pipe, T, into the condenser. The inner end of this pipe is fitted with a rose, so that the water is scattered in a fine shower, and thus condenses the steam very rapidly, so that a considerable degree of exhaustion is maintained. A pressure gauge is usually affixed to the condenser, so as to indicate readily the exact degree of condensation produced.

By the use of this arrangement the condensation is practically instantaneous, and there is no delay in commencing the alternate stroke. The injected water added to that produced by the condensation of the steam accumulates in the condenser, and would soon impede its action were no means provided for removing it, and any air which may find its way in with it. An air-pump, M, is therefore placed by its side, and motion is imparted to it by means of the pump-rod, F, which is affixed to one rod of the parallel motion.

A pipe, closed by a valve opening outwards, leads from the lower end of the condenser to this pump, and along this the condensed water and the air pass, and are delivered into the hot cistern, N. The air, of course, bubbles up through the water and escapes.

The steam when it leaves the cylinder has still a large amount of heat stored up in it, and this raises the temperature of the injected water, so that the water in N is quite hot. It is used, therefore, to feed the boiler, into which it is injected by the pump, Q, along the feed-pipe, S. As much of the heat in the steam is latent, a large amount of water is required to condense it. If the condensing water has a temperature of about 60° while the temperature when condensed is 100° or 120°, nearly twenty pounds of water will be required to one pound of steam. This is, of course, very much more than is required for feeding the boiler; and hence, in many engines, arrangements are made by which a portion of the condensed water leaves the condenser at a temperature very little below the boiling-point, and with this the boiler is fed. The more usual plan, however, is for the feed-water to have a temperature of about 120°.

Various other kinds of condensers are often employed in place of that already described. In steam vessels "surface condensers" are commonly adopted. In these the steam is made to pass through a series of brass or copper tubes, on the exterior of which the cold water plays, and thus condenses the steam. In other cases the positions are reversed, the water being made to pass through the tubes while the steam is condensed upon their external surfaces, and this plan appears to meet with more general approval. In this kind of condenser it is well to let the circulation be as rapid as possible, and the more rapid it is the less the area of condensing surface that will be necessary to ensure efficiency. The usual proportion allowed is from twelve to eighteen square feet for each nominal horse-power of the engine, but with a rapid circulation less than this will suffice. There must, however, be no delay in the condensation, or else a resistance will be offered to the movement of the piston.

The supply of the water and steam should be so arranged that the steam as it enters the condenser is first exposed to the action of the heated water just leaving it. In this way the cold water entering meets the steam when its condensation is nearly completed. Condensers of this kind answer very well, but it is not often found necessary to employ them except in the case of marine engines.

We have now referred to the various parts of the engine that are shown in Fig. 32: there is, however, one important part omitted there. In most cases it is an important thing to maintain a nearly uniform rate of motion. Without some regulator, however, this cannot be attained; the pressure of steam in the boilers often varies considerably from time to time; the load of the engine is also subject to constant fluctuations; and in a large factory some of the machines are frequently stopped for a time, and others again are set to work. The tendency of all these alterations is to produce great variations and irregularities in the speed of the engine, and cause thereby much inconvenience.

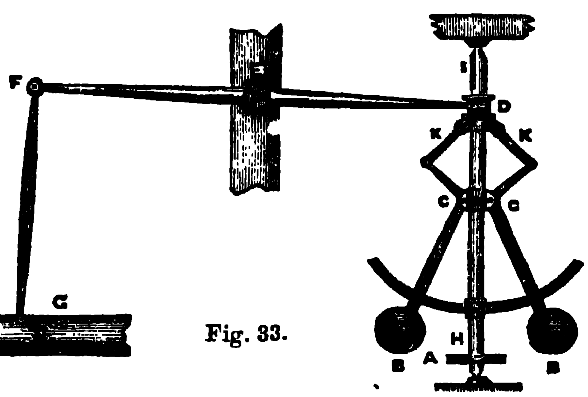


Fig. 33.

The manner in which the speed is usually regulated is by means of a throttle-valve, acted upon by governor balls, as seen in Fig. 33. This valve consists of a metal disc, G, placed in the steam-pipe; it is mounted on an axis passing through it edgeways, so that when it is horizontal the passage of the steam is not materially affected, but as it is inclined the passage becomes more and more closed. In some convenient part of the engine is placed a vertical axis, H I, mounted on pivots at each end, and driven by an endless band passing round the driving pulley A, and also round the axis of the fly-wheel or some similar part. On this axis are jointed two bent levers, C B, C B, each of which carries at its lower end a heavy metal ball, B.

Above C C is a loose collar, D, supported by two rods, K K, hinged to the other ends of the levers, and moved by them. A groove in this collar holds two pins in the crutch of the lever, D E F, and thus moves the throttle-valve, G. If now the load of the engine be diminished, or from any other cause the speed increase, the balls at once, by centrifugal force, fly further apart. In so doing they raise the upper ends of the bent levers, and with them the collar D. The result of this is that the end, F, of the lever is depressed and the valve partially closed, and the supply of steam being in this way diminished, the speed of the engine is at once reduced. If on the other hand the engine moves more slowly, the governor balls fall, and thus open the throttle-valve to a greater extent. In this way the speed is maintained very nearly at a uniform rate. In some engines now made, the governor balls, instead of working a throttle-valve, are connected with a second slide-valve, and thus alter the period of the stroke at which the steam is cut off, and in this way regulate the speed.

A regulator of the kind already described is that most generally used. Its action is, however, far from perfect, as it takes some little time for the engine to recover its rate of speed after a sudden variation in the load. Many alterations have been suggested; in some of these the governor balls are retained, but the construction of the valve is very materially modified, so as to render it much more sensitive. In one form, which has been found to answer well, a double spindle valve is used in place of the disc, two valves being mounted on the same spindle, so that a trifling movement of this materially alters the rate at which the steam is allowed to pass.

Before passing on to notice the construction of other kinds of engines, it will be well to explain the manner in which the power of an engine is described. In reading any books or papers relative to engines we constantly find the term "horse-power," the engine being said to have so many horse-power.

Now it is important for us clearly to understand what is meant by this expression, especially as it is often somewhat vaguely employed, being in some cases used to denote "nominal" power, and in others "actual" power. The latter, of course, varies with the pressure of the steam employed, but the former is an arbitrary term expressive of the size of the engine, and may generally be taken as expressing the actual power when the steam has a working pressure of 7 pounds to the inch in the case of a low-pressure engine, and 21 pounds in the case of a high-pressure engine. The actual steam pressure usually exceeds this, and as a result the actual power of any engine is usually much in excess of the nominal.

The term "horse-power" was originally an arbitrary standard taken to express the work capable of being, under ordinary circumstances, performed by a horse, and is now used as expressive of a force capable of raising 33,000 pounds to the height of one foot in the space of a minute. The actual horse-power of any engine may therefore be easily calculated.

By means of an "indicator" or gauge the actual pressure in the cylinder is ascertained, and from this a deduction of 1½ pounds is made to allow for loss by friction, imperfect vacuum in the condenser, and similar causes. We then ascertain the area of the piston in square inches, and multiplying this by the working pressure obtained, as just explained, we find the total pressure on the piston.

Now multiply the number of strokes performed in a minute by the actual length of each, and we shall thus learn the space traversed by the piston in feet. Multiplying this by the total pressure, and dividing by 33,000, we have the actual horse-power.

The rule for calculating this should be carefully remembered, as it is often required, and it may be simply expressed in the following form:—

From the pressure of the steam, expressed in pounds per square inch, deduct 1½ pounds for loss, and multiply the area of the piston in square inches by the remainder; then multiply this amount by the space travelled by the piston per minute expressed in feet, and divide by 33,000; the quotient will be the actual horse-power.

An example will render this perfectly plain. Let us suppose an engine whose piston has an area of 200 square inches, and the length of whose stroke is two feet. Further, let it make sixty complete strokes or double movements of the piston per minute, and let the pressure of the steam [illegible] twelve pounds per square inch. What is its actual power?

The pressure exerted on the piston by steam in this case is 200 × 10½, or 2,100 lb., and the space travelled over by the piston in each minute is 120 × 2, or 240 feet. The work accomplished, therefore, is $2,100 \times 240 = 504,000$ foot-pounds, and the horse-power, therefore, is $\frac{504,000}{33,000}$, or a little over 15. If in any of these cases the vacuum in the condenser is imperfect, there is a corresponding pressure opposed to that of the steam, and this must be allowed for in calculating the power.

The nominal power is, as we have said, an arbitrary expression, and is nearly always considerably below the actual power, being often as low as from a fourth to an eighth of it.

The formula usually employed for calculating this is known as the Admiralty rule, and is as follows, $\frac{d^2v}{6000}$, where d is the diameter of the piston expressed in inches, and v the velocity of the piston expressed in feet per minute.

We can now apply this rule to the case just given, but must first ascertain the diameter of the piston, and since its area is 200 square inches, this is about 16 inches. The formula $\frac{d^2v}{6000}$ therefore becomes $\frac{16 \times 16 \times 240}{6000} = \frac{6144}{600} = 10\frac{1}{4}$ nearly.

This, then, is the nominal horse-power of the engine.

The same term is frequently applied to a boiler as expressive of its size and capabilities; but it is very evident that in this case its meaning is somewhat different. An engine of one horse-power will, as we have seen, exert a force equivalent to raising 33,000 lb. a foot high per minute. In an hour, therefore, it would raise nearly 2,000,000 lb. to the same height. Now we have seen that the evaporation of a cubic inch of water exerts a force equivalent to raising a ton a foot high; to raise the 2,000,000 lb., therefore, will require the evaporation of nearly 1,000 cubic inches of water. A considerable portion of the force thus produced is, however, employed in moving the engine itself, and wasted or lost in various other ways, so that a much larger quantity of water must be evaporated by the boiler to accomplish the amount of work required.

Allowing for all these sources of waste, engineers calculate that as a general rule a boiler should evaporate one cubic foot of water per hour for each horse-power of the engine. This is therefore taken as the standard; and thus, when a boiler of 50 horse-power is spoken of, we at once understand that one is meant which is, under ordinary circumstances, capable of evaporating fifty cubic feet of water per hour.

Fig. 34.

There is a small but very important piece of apparatus that is frequently attached to one end of the cylinder of an engine, and known as the "indicator," to which we must here refer. The pressure of the steam in the cylinder is often very different from that in the boiler, as the size of the steam-pipes and ports considerably modify it. We require, therefore, in order to tell accurately the power of the engine, some means of ascertaining the pressure in the cylinder during the stroke. The vacuum in the condenser may likewise become imperfect, owing to the air-pump being out of order, or from some other cause, and we want in some way to be apprised of the fact. Both these ends are accomplished by means of the indicator, which is shown in Fig. 34. It consists of a brass cylinder, *a*, some ten or twelve inches long, and about two inches internal diameter; it is very truly turned inside, and has a solid piston or plunger, *b*, fitting it accurately. To the upper extremity of the piston-rod a pencil, *g*, is firmly fixed, so as to record on a card suitably placed the movements of the piston. At the lower end a screw is cut, by which it is usually affixed to the upper end of the cylinder, a stop-cock, *e*, being placed so as to cut off the communication when it is not required to use the instrument; a spiral spring is fixed to the piston, *b*, and at the upper end to a ring or fastening, *c*, fixed in a suitable position; this is so arranged that when the spring is in its normal state, the piston is about the middle of the cylinder. The spring can, however, be compressed or extended. A card, *f*, is mounted in a frame placed above the indicator, and made to move backwards and forwards with the motion of the piston. This is usually accomplished by a cord passing round a pulley, and fastened to some convenient part of the engine. This cord pulls the card one way, and as soon as the motion of the piston is reversed, a spring or weight brings it back to its original position. When the stop-cock, *e*, is closed, the pencil is at rest, and a horizontal line is therefore traced on the card as it moves to and fro; but as soon as the steam is allowed to enter the indicator, the pencil moves up and down, and a figure is traced on the card which indicates to an experienced eye the action of the engine.

Let *e* be turned on just as the steam is admitted to the upper end of the cylinder, the piston *b* will be immediately forced up, and trace an almost vertical line; the full pressure is not, however, instantly attained, and hence the line continues for a little way to slope upwards. If the steam is cut off at a third, or any other portion of the stroke, the line immediately tends downwards, and by its rapid fall indicates the decreasing pressure, until the piston arrives at the lower end of the cylinder.

The upper end is now put into communication with the condenser, and if the vacuum there be good, it will be indicated by a sudden fall in the curve. The pressure of the air being allowed to act freely on the upper side of the piston, it will by this be depressed below the normal line, the spring being extended by the pressure, and the lower the piston sinks the more perfect does it show the vacuum to be. It is comparatively easy to graduate the card so as to show at a glance the exact pressure, and also the degree of vacuum in the condenser; and the further these extremes are removed from one another, the greater is the power of the engine. We may, in fact, obtain a general idea of its action from the area of the figure traced on the card; for the larger this is, and the more closely approaching to a parallelogram, the more perfect is the action of the engine.

Apart from showing in this way the power, the indicator diagram is of very great service in showing the action of the valves. If, at the extreme right of the figure, the line descends but slowly, it clearly shows that the communication with the exhaust is made too slowly, or else that condensation does not proceed with sufficient rapidity. The more vertical the line is here, the better is the action of the condenser. The ascending stroke at the other end of the card should likewise be nearly vertical; but to an experienced engineer each corner of the diagram will indicate some peculiarity in the action of the "lap" or "lead" of the valve, and thus enable him at once to point out and rectify any defects. We can, however, only just point out the broad principle of this very valuable piece of mechanism, and for full details must refer the student to some of the various works that inquire fully into the indicator and the indicator diagram.

AGRICULTURAL DRAINAGE AND IRRIGATION.—VIII.

By Professor Wrightson, Royal Agricultural College, Cirencester.

SEWAGE IRRIGATION.

The sewage question is interesting and important from two aspects: first, because it touches the sanitary condition of the country; and, secondly, as an agricultural problem. The pollution of our rivers has been the first and most distressing effect of a large population and a defective sewage system; and the loss of an immense mass of valuable fertilising material has been the second, although less urgently pressing, inducement to action. Hence the sewage question claims attention alike from town and country; and it is not surprising that every intelligent person throughout the kingdom should be more or less interested by it. The problem is simplified by the admirable manner in which the agricultural requirements meet those of a more purely sanitary character. If the rivers cry out against an influx of filth, the land calls as loudly for material to restore its waning fertility; hence, both the land and water are grateful when sewage is diverted from the rivers and poured over the fields. Time is required to show how far such a system can be generally and successfully applied. The soil possesses a wonderful deodorising and decolorising power, and filthy water, after having passed through a layer or filter of earth, comes forth more or less purified. Soil has also been shown, of late years, to be capable of removing some of the most important elements of fertility from solution, and holding them until they are required as plant-food. This power is not yet fully understood, but it is supposed to resemble that possessed by woollen cloth for fixing colouring matter used in dyeing, or the power by which charcoal acts in purifying sugar. Hence, soil is well calculated both to render sewage innocuous, and to conserve its valuable fertilising qualities. The only questions are: How far these powers possessed by soils are likely to be persistent in any particular case? how far the produce of such land will continue to be wholesome? and how far the sewage will continue to flow from the area devoted to it as a *pure* stream? We are thus introduced to the subject of "sewage irrigation," offering, as it does, a simple solution to an important national question. Divert the streams of sewage from their course towards the neighbouring river; construct a series of water-meadows, or fields for cultivation, laid out upon a similar principle, and allow the fertilising flood to expand over their surface; let the purified water again be collected by ditches and discharged into the river at a lower level. Such is the simple plan proposed, and in many cases carried out with success, up to the present time.

Before entering more into detail with reference to cases in which this principle has been adopted, I shall point out the advantages it presents over rival systems for utilising sewage. It deals with sewage *as it is*. There seems to be little reason for expecting that the population of this country will abandon the water-closet. Earth and ashes may in country places be advantageously substituted for water, as has been shown by the Rev. H. Moule, but such a plan is not likely to meet with favour in towns, and appears impracticable for such gigantic centres of population as London, Birmingham, and Liverpool. If it be granted that water will continue to be the vehicle for carrying away urban *excreta*, then we have irrigation as the sole means by which it can be advantageously applied. Schemes have indeed been proposed by which the valuable matter contained in sewage, as well as the deleterious and offensive matter associated with it, should be precipitated, collected, dried, and used as a manure, while the water, freed from its impurities, should then flow harmlessly on its course. Feasible as such a proposal may at first sight appear, it is beset with difficulty. The value of sewage does not depend upon its filthiness, but upon certain ingredients which occur in very small quantities. Robbed of these, the sewage water would be valueless, and any system of sewage utilisation, on the principle of precipitation, must provide that these valuable ingredients be arrested in the precipitated mass. This, however, is a difficulty which appears insurmountable. First, because these valuable ingredients—ammonia and potash—are exceedingly loth to quit their soluble condition under any circumstances, and especially when mingled with such a mass of water as in town sewage. The consequence is that, precipitate as you like, or with what you please, the ammonia and potash will flow away in the "purified" water, and the remaining mass, whether it be named A B C or X Y Z, will be of small fertilising value. From these considerations it is evident that as yet no plan based upon the principle of precipitation is likely to succeed, and that irrigation is the only alternative.

We have, then, to do with an immense mass of sewage, the character of which we must very briefly consider. Sewage consists of the entire water-supply of our towns after it has been used for domestic purposes, of the excreta of man and animals, of the rainfall of the town area, and of earthy matter washed and worn from the streets. It contains valuable fertilising matter in an extremely dilute condition. This can be demonstrated by analysis, and many eminent chemists having examined town sewage at various times, have given us a tolerably accurate idea of its composition. Phosphoric acid, nitrogen, and potash, are the three principal ingredients of agricultural importance. These substances can be purchased in the form of guano, "superphosphates," potash salts, and other manures; and since these substances are marketable, an estimate can readily be formed as to the cheapest rate at which they may be obtained. Thus, it may be shown that ammonia may be purchased in the form of some manurial substance at the rate of, say, £60 per ton. Hence, a commercial value may be attached to the three substances above mentioned, and by finding the proportion in which they exist in town sewage, an estimate may be formed as to its value. It is needless here to enter further into detail, and it is sufficient to state that the value of sewage calculated upon purely chemical grounds is 1·8d. per ton, varying, of course, according to season and other conditions. The result of sewage irrigation agrees closely with this estimate, being more usually below than above it. Thus, in the case of Rugby, where the effects of sewage were closely watched by a Royal Commission, the Commission lost money upon the sewage, contracted for at 1d. per ton. On the Barking Creek farm the result of sewage application was approximately that 100 tons of sewage yielded 1 ton of grass, and if this were worth 10s., then 100 tons yielded 10s., or at the rate of 1·2d. per ton.* It is only fair to state that Mr. Mechi, who converts the whole of his farm manure into the liquid form, obtains very superior results to those just given; but it must be remembered that Mr. Mechi has perfect control over the composition of the liquid manure used at Tiptree, which is, probably, frequently more concentrated than town sewage. Also, at Tiptree the liquid dressing is applied *when it is required;* whereas in the utilisation of town sewage it is necessary to pour the water over the land at all seasons, whether required or not. We have, then, to do with a substance of trifling value per ton, although of high value when we reflect upon its immense quantity. The question is therefore as follows: How is a substance valued at from 1d. to 2d. per ton to be economically applied to the land? How can we carry such a *worthless* material for miles into the country, and apply it for purposes of cultivation? The answer is simple. It cannot be applied advantageously where any appreciable cost per ton must be incurred. Pumps, expensive pipes, and business expenses, are serious difficulties in sewage application, and success will probably only ensue where *gravity* is the sole force for conveying the sewage to its destination. The estimated value of sewage depends upon chemical analysis, and upon results obtained at Rugby and elsewhere from its use. Both methods, however, fail in precision: the first, because the value of the water as an essential element in the development of plants is not considered; and the second, because the sewage has never been applied under conditions calculated to bring out its maximum effects. Could the use of sewage be restricted to seasons of the year when water is most needed, and could it then be applied to plants capable of making the greatest use of it, results far superior to any yet recorded might be obtained. It is, indeed, probable that the success attending liquid manuring at Tiptree and elsewhere may be thus accounted for, as in such cases thorough control can be exercised. In dealing with the drainage of a large town, *storing* the sewage cannot be contemplated. At the same time much may be done towards its profitable application by so dividing the fields over which it flows, that crops may be grown requiring it at different periods. This has been done with success at Barking Creek farm, where rye-grass, cereals, flax, mangold, strawberries, etc., are very successfully cultivated with the aid of sewage.

I shall now mention a few cases in which the drainage of towns has been used for irrigating land. Edinburgh offers one of the oldest examples. There the sewage is allowed to flow over a tract of about 300 acres, with good results *per acre*, but the amount realised per ton of sewage is difficult to estimate, on account of the vast mass of water employed. The produce per acre per annum is from £20 to £30 worth of grass, sold to the cow-keepers of the city. The quality of the land is exceedingly poor, being little better than sand, a fact which has given countenance to the scheme of the Essex Reclamation Company for pouring the sewage of North London over the Maplin Sands. It is worthy of remark, that immense as is the mass of water used per acre in the case of the Edinburgh meadows, any attempt to enlarge the area of irrigated surface has been attended with a diminished yield over the remainder. Another curious fact is, that although sewage is capable of raising large crops of grass, the fertility of the soil does not appear to be increased. This fact has been pointed out by Messrs. Lawes and Gilbert, in their experiments at Rugby, where land, which had produced large crops under the influence of sewage, immediately fell back to its old standard of productiveness when the supply of sewage was withdrawn. The authorities just named made a series of experiments upon the use of sewage in the neighbourhood of Rugby. They employed the large quantities of 3,000, 6,000, and 9,000 tons of sewage per acre respectively, upon contiguous plots, and found that each additional quantity was followed by an increase of crop, although the amount of grass per 100 tons of sewage used was less in the case of the heavy dressing. This, taken in connection with a similar result obtained at Edinburgh, is interesting, as showing the large amounts of this material which may be advantageously applied to land. Further, at Rugby it was found that although a large quantity of grass was grown, the quality of the herbage suffered under the system of sewage irrigation.

The utilisation of the Croydon sewage has very often been cited as a successful enterprise. In this instance, sanitary considerations have been the chief inducement to action, and the writer will never forget one proof that, from this point of view the success has been most complete. On a hot day in July he arrived at Beddington, and was kindly received by Mr. Marriage, the lessee of the irrigated land. Among other refreshment, two bottles were placed upon the table, the one containing a wine, the other a colourless fluid (not whisky), which was neither more nor less than purified *sewage*. It appears that visitors to the irrigated fields are given the choice between wine and a sample of purified sewage, in order that they may thus test the complete success of the process used. The appearance of the liquid and the absence of smell betokened the removal of all unwholesome matter. The sewaged fields at Croydon yielded a rent of £5 per acre to the lessors in 1868, but the old lease was then just falling in. Italian rye-grass was the crop exclusively grown, and this required frequent renewal, as in a year or two its place was usurped by "water-grass." Frequent re-sowings have also been found necessary at Barking Creek farm. During the dry season of 1868 I was informed that the irrigated lands at Beddington suffered from the drought, although supplied with an almost unlimited amount of water. Here the sewage alternately spreads over fields, and is collected by ditches three times in succession, after which it flows into the river. The exit of the stream of purified sewage is periodically inspected, and the condition of the water reported upon.

In the foregoing remarks upon sewage irrigation the subject has been treated very generally. The mass of published statistical information is exceedingly large, and in order to enter into details much more space would be necessary than is here allotted to the subject. The object of the writer has therefore been to introduce as many interesting facts as possible in connection with a subject which, in the preceding short essay, has been little more than outlined.

PRACTICAL PERSPECTIVE.—VII.

HITHERTO all the planes and objects delineated have been supposed to be so placed that some of their lines are parallel, and others at right angles to the plane of the picture.

We now enter upon the system by which perspective projections are made when the sides of the plane or object recede from the picture at angles other than right angles.

Reverting to Fig. 4 (Vol. I., page 293), it will be remembered that the triangle E C F was supposed to be laid down so that the points G and H were obtained on the horizontal line; and these represented the true distance of the spectator from the picture.

In the system now under consideration, a similar triangle, A C B, standing on the line A B, is supposed to be laid down below or above the horizontal line; and this will give the point I, the station-point of the spectator. The line I D is then called the *line of direction*, as indicating the direction of the central ray, or axis of the cone of rays.

With this brief introduction, it will, it is hoped, be found possible for the student to follow the lessons. These are most carefully graduated, not merely according to theory, but from *absolute practice* in teaching. We will therefore at once proceed to

Fig. 34.—Here, having drawn the picture-line and the horizontal line, and having fixed the centre of the picture and the line of direction, the length of which is determined by the distance of the spectator from the picture, draw a horizontal line at S. Thus far for the height and distance of the spectator.

The next question is this—What angles do the sides of the object make with the picture-plane?

This must, of course, depend on the plan given in Fig. 35.

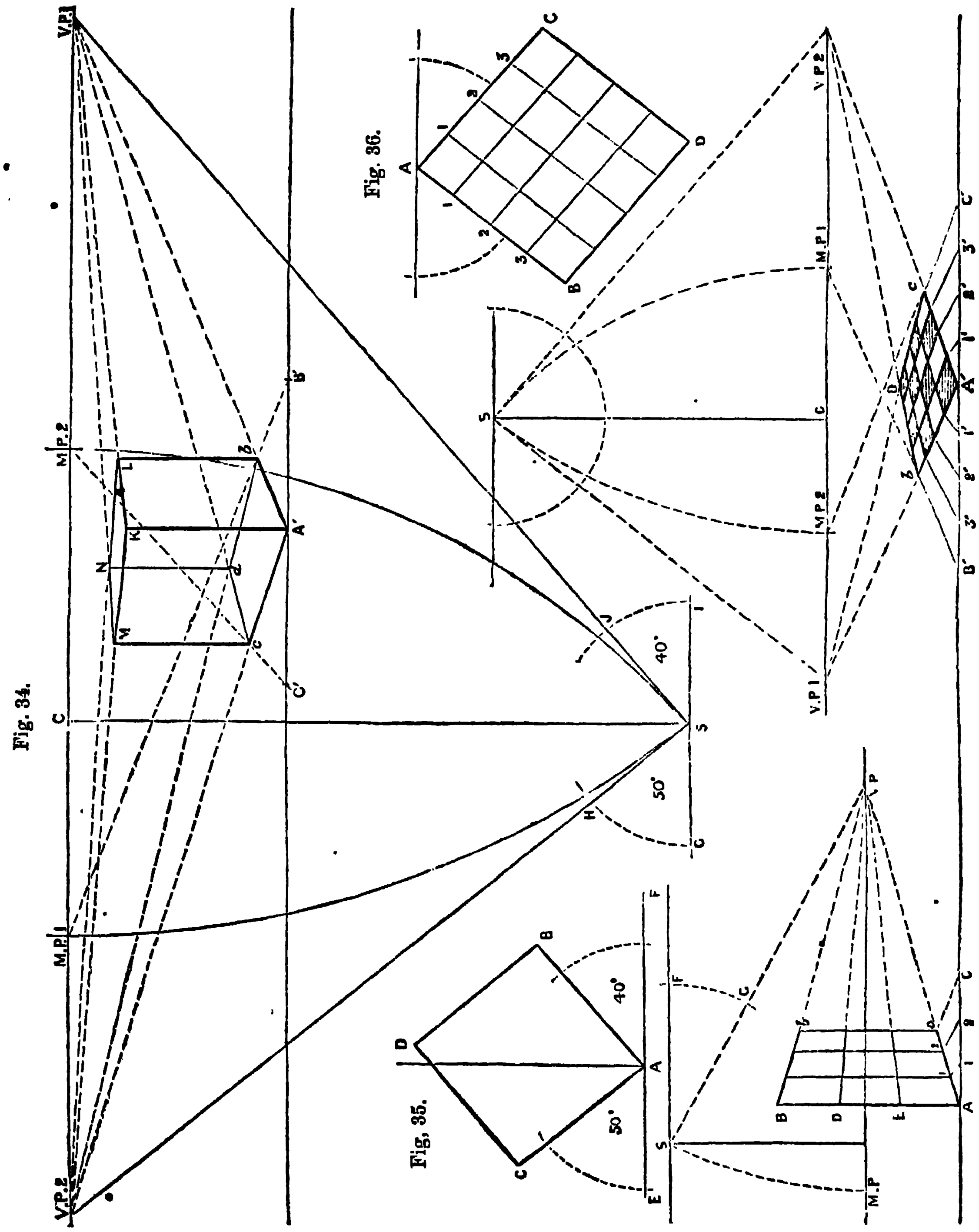
Here E F is the base-line, or line on which the picture-plane is to stand; and the square A B D C is the plan of the plane to be put into perspective.

From this it will be seen that the angle F A B is one of 40°, and the angle E A C one of 50°, with the plane of the picture.

Returning now to Fig. 34, and having drawn a line at S parallel to the picture-line, on each side of the point S construct angles corresponding with the angles which the lines of the plan make with the line E F—viz., G S H and I S J. In this case these angles are known to be 50° and 40°; but as a rule, if a plan be given, the angles at the station-point may be constructed similar to those of the plan by the method shown in Fig. 18 of "Practical Geometry applied to Linear Drawing" (Vol. I., page 124).

Produce the lines S H and S J until they meet the horizontal line; and these points of meeting are called the *vanishing* *points* for these lines. Call the one V P 1 (vanishing point No. 1), and the other V P 2.

From V P 1, with radius V P 1 to S, describe an arc, cutting the horizontal line. Call this intersection M P 1 (*measuring point* No. 1). From V P 2, with radius V P 2 to S, describe an arc, cutting the horizontal line in M P 2 (measuring point No. 2).



The reason why these points are called *measuring* points will be understood when their use in measuring is seen as we proceed.

All the points necessary for our present purpose having been fixed, we can now proceed with our perspective projection.

Having fixed that the angle A of the plan shall be at A′ on the picture-line, draw a line from A′ to each of the vanishing points.

Now it will be remembered that when in former studies a line was supposed to be receding from the picture-plane at right angles to it, and it was required to cut off a certain portion of that line, or to mark a particular point upon it, the real length to be cut off was marked on the picture-line, and a line drawn to the point of *distance*, intersecting the original line in a point required. In the present system of perspective, *the measuring points are used for this purpose*, as will be seen by the following process:—

From A′ set off on the picture-line the length A′ B′ and A′ C′. equal to A B and A C, the sides of the plan. From B′ draw a line to the measuring point belonging to the vanishing point to which the line which is to be cut off is drawn. Thus the line we are now considering is drawn from A′ to V P 1; therefore, from B′ draw a line to M P 1, which cutting the line A′ V P 1, gives the intersection *b*, which is the point required; and A′*b* is the perspective representation of the line A D of the plan when receding at 40° from the picture.

Similarly, draw a line from A′ to V P 2; and from C′ draw a line to M P 2, cutting A′ V P 2 in *c*. Then, as in the former case, A′ *c* is the perspective representation of the line A C of the plan.

It is here necessary to bear in mind a short rule—viz., *all lines which in the object are parallel to each other vanish in the same point.*

Now, on referring to the plan, it will be seen that the line B D is parallel to A C, and that the line C D is parallel to A B.

Therefore, in the perspective projection, these lines will vanish in the same points.

From *b* draw a line to V P 2, and from *c* draw a line to V P 1.

These lines intersecting in *d* (which corresponds with D in the plan) will give A′ *b d c* as the perspective representation of the plane A B D C when placed at the angles of 40° and 50° to the picture-plane.

Let us take Fig. 35, however, to be not a *single plane*, but the plan of a cube, the faces of which are at the stated angles to the picture-plane.

Then, having projected the plan already shown, erect a perpendicular at A′—viz., A′ K. This perpendicular is to be the *real* height of the foremost edge of the object, whatever that may be. But as in this case a cube is the subject of the study, the edge A K will of course be equal to any one of the edges of the plan—viz., A B, A C, B D, or C D.

Now the upper edges of the cube are parallel to the lower ones, and therefore they will vanish to the same points.

Therefore from K draw lines to both vanishing points.

From *b* and *c* draw perpendiculars cutting the lines drawn from K in L and M.

From L and M draw lines to V P 1 and V P 2, and these, intersecting in N, will complete the representation of the cube.

It will prevent the student experiencing much disappointment in his results if he bears in mind that when the angle on each side of the station-point has been constructed, the space contained between these two angles should correspond with the angle of the object itself; thus, when an angle of 50° has been constructed on the one side of S, and an angle of 40° on the other, then the angle G S H remaining between them should be the angle of the object, which in the present instance is a right angle.

It is also necessary to point out when a rectangular object, such as a cube, stands at equal angles to the picture-plane—that is, when it recedes on each side at 45°—the points of distance become the vanishing points.

Fig. 36.—In this figure the rule, that "all lines which in the object are parallel to each other vanish in the same point," is plainly illustrated.

Here the subject is a square, divided into smaller squares by lines parallel to the sides.

Having drawn the picture-line, horizontal line, and line of direction, find the vanishing points and measuring points, as in the former case; it has already been stated that the station-point may be taken below or above the horizontal line. The latter is chosen in the present study.

The angle A of the plan (Fig. 37) being fixed at A′, draw lines to the vanishing points.

From A′ set off A′ B′ and A′ C′ equal to the sides of the square, and from these points draw lines to the measuring points, which, cutting the lines drawn to the vanishing points, will give the points *b* and *c*, completing the perspective view of the external square.

Set off on the picture-line between A′ and B′ and A′ and C′ the points 1′, 2′, 3′, corresponding with those similarly figured in the plan. From 1, 2, 3 draw lines to the measuring points, cutting A′ *b* and A′ *c*, and from such intersections draw lines to the vanishing points, which, crossing each other, will divide the square as required, and will thus complete the perspective representation of the original figure.

Fig. 38.—This is another adaptation of the same study, and gives the principles on which windows, doors, etc., in buildings standing at an angle to the picture, are drawn.

The height of the spectator and the distance having been fixed, let us suppose that the angle at which the plane is to be represented is that shown at S—viz., F S G.

Produce S G until it cuts the horizontal line in V P. From V P, with radius to S, describe an arc, cutting the horizontal line in M P.

Draw A B, the vertical edge of the plane to be drawn, and from its extremities draw lines to the vanishing points.

From A set off A C equal to the width of the plane, and draw a line to the measuring point, which, cutting A V P in *c*, will give the plane for the distant vertical side *c b*.

Now on A B set off the required points of division, E and D, and from these draw lines to the vanishing point, which will divide the plane into three strips, which, if it were parallel to the plane of the picture, would be horizontally placed.

Between A and C set off the points 1, 2, representing the widths into which the plane is divided vertically, and from these points draw lines to the measuring point, cutting A *c* in 1, 2; on these erect perpendiculars, which will complete the figure.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

X.—GALILEI GALILEO.

BY JAMES GRANT.

GALILEI GALILEO, the inventor of the telescope—one of the most distinguished of Italian philosophers—was born in the city of Pisa, about the year 1564. His father, a Florentine noble, had him educated for the profession of medicine; but a love for geometry inspired him, and to this study he turned all the powers of his mind. The writings of Archimedes and Euclid he mastered without the aid of a tutor; and so great were his acquirements, that in his twenty-fifth year he was appointed by Cosmo II., then Grand Duke of Tuscany, to the mathematical chair in Pisa. Before three years were passed he had to quit that city, his sturdy opposition to the philosophy of Aristotle having gained him many enemies; so he accepted the professorship of mathematics in the then famous University of Padua, where for eighteen years his name adorned it, and he succeeded in developing a high taste for the physical sciences.

Galileo had distinguished himself by no discovery (a few minor contrivances excepted) till he attained his forty-fifth year. This was in 1609, when he produced a telescope: and perhaps no invention that science has presented to mankind is so boundless in its influence, and so extraordinary in its nature, as that long glass by which distant objects are viewed clearly. It chanced that in 1609—the same year in which Kepler published his "Commentary on Mars"—Galileo was in Venice, when, in the course of conversation, he heard it stated that "a Dutchman, named Jansen, had constructed and presented to Maurice, Prince of Nassau, an instrument through which he saw distant objects magnified and rendered so distinct that they seemed close to the observer." Struck by this story, which a few believed and many discredited, the mind of Galileo became filled with the importance of such an instrument; and so thoroughly had he already studied the entire science of lenses, that he not only discovered the principle of their application in a shifting tube, but was speedily able to make a telescope for his own use. To the uninstructed mind the power of seeing clearly objects at a vast distance brought close and nigh apparently, must seem miraculous; and hence it was that the Arabs, whom the officers of Colonel Malcolm's force in Persia permitted to look through their telescopes, fled in terror, exclaiming, "You are magicians! Now we see how you take towns; that thing, be they ever so far off, brings them as close as you like." It was an invention valuable alike for peace and war; but to have been the first astronomer in whose hands so valuable a gift was placed, was an eminence to which Galileo owed all his reputation and future persecution.

As soon as his telescope was complete he applied it to the stars of the firmament, and on the night of the 7th of January, 1610, when first he used it, he saw close to Jupiter three little bright stars, hitherto unseen by human eye, lying in a line parallel to the ecliptic, two to the east and one to the west of the planet. Then a great emotion of enthusiasm is said to have filled his heart; but regarding them as merely ordinary stars, he never thought of estimating their distances. But on the night of the 8th of January, when again regarding Jupiter, he was surprised to see all the three stars to the west of the planet. It was requisite that the motion of Jupiter should be direct to produce this effect, whereas it was distinctly retrograde. On the 10th he could distinguish only two stars to the east of the planet, the motion of which he was quite unable to explain. He ascribed the change to the stars themselves, and on the night of the 11th he no longer doubted that he had discovered three planets that revolved round Jupiter; and on the 13th he saw, for the first time, the greater planet's fourth satellite.

This discovery cast a new light on the entire celestial system. Hitherto it had been believed that while this earth was the only planet favoured with the existence of a moon, it was of necessity the only one in the universe that was habitable, and as such occupied pre-eminence in being the centre of the system; but the discovery of *four* moons revolving round a much nobler planet than ours, deprived the old argument of all force, and established a new analogy to it and the other heavenly bodies.

In 1610 Galileo, in his "Sidereal Messenger," announced his great astronomical discovery to the then very limited world of science. Kepler perused it with the deepest interest; for while it confirmed and extended his own brilliant discoveries, it dispelled the old illusions of past philosophy; and in the "Dissertation" which he published on the discovery of the learned Pisan, he expressed a hope that similar satellites might be traced around Mars and Saturn. Galileo next applied his wonderful glass to the study of Venus, and in 1610 discovered in the phases of that planet the forms of waxing and waning peculiar to the moon. He next detected the spots on the face of the sun, ascribing them to the rotation of the central luminary; and on the surface of our moon he saw her valleys in shadow, her mountains in light, and determined the curious fact of her balance or trepidation in the firmament, in virtue of which parts of her shining disc occasionally appear and disappear.

It was while thus occupied in his native city of Pisa—to which he had been recalled by the Grand Duke Cosmo, ever his generous patron, that he might pursue his astronomical studies—that the fame of his discoveries spread over all Europe, and many learned men, who had been obstinate adherents of more ancient systems, felt themselves compelled to acknowledge the truth of the new. But Galileo, though ambitious of propagating the new truths which he wished to establish as to the working of the solar system, had mistaken the general disposition of mankind, and the narrow prejudices of the age in which he lived. "That same system of the heavenly bodies which had been discovered by the humble ecclesiastic Nicholas Copernicus, which had been patronised by the kindness of a bishop, published at the expense of a cardinal, and which the Pope himself had sanctioned by the warmest reception, was, after the lapse of a hundred years, doomed to the most violent opposition as subversive to the Christian faith. On no former occasion had the human mind exhibited such a fatal relapse into intolerance." So the clergy became the most bitter opponents of Galileo, and were resolved to persecute him even unto death, if possible, becoming for the time thorough barriers to the progress of science.

Thus in the year 1615, in consequence of complaints laid before the Holy Inquisition, Galileo was summoned to Rome, that he might answer for the foul heretical opinions he had promulgated verbally and in writing. He was charged with "maintaining as true the false doctrines held by many, that the sun was immovable in the centre of the world, and that the earth revolved with a diurnal motion; with having certain disciples to whom he taught this false doctrine; with keeping up a correspondence on the subject with several German mathematicians; with having published letters on the solar spots, in which he explained the same false doctrine as true; and with having glossed over with a false interpretation those passages of the Scripture which were urged against it."

In February, 1616, the consideration of these charges came before a meeting of the Holy Office, and the court avowing their desire to deal gently with the prisoner, issued the following decree:—"That his Eminence Cardinal Bellarmin should enjoin Galileo to renounce entirely the above cited false and heretical opinions; that on his refusal to do so he should be *commanded* by the Commissary of the Inquisition to abandon the said doctrine, and to cease to teach and defend it; and that if he did not obey this command he should be thrown into prison."

Galileo appeared before Cardinal Bellarmin on the 26th of the same month, and after receiving from him some gentle admonitions, the Commissary, in pursuance of remit made to him, commanded the astronomer, in presence of a notary and certain witnesses, to abstain altogether from the diffusion of his erroneous opinions, as it was now unlawful for him to teach them in any way whatever, either orally or in writing. To these absurd injunctions Galileo was compelled to promise obedience, and was passed through the perilous gates of the Inquisition. To the influence of the Grand Duke Cosmo, and many other Tuscans of high rank, the mildness of this sentence must be ascribed. Nor was the Papal Court itself without many high ecclesiastics who took a deep interest in the trial of one who was by most men considered as the pride of Italy. However, so great was the dread of the officials of the Holy Office that he might not be deterred by threats from propagating his obnoxious doctrines concerning the motion of the earth round the sun and so forth, that a stern decree was issued denouncing them as false, contrary to the writings of the Fathers, and prohibiting the sale of every book in which they should be maintained.

Returned now to the Tuscan capital, Galileo resumed his studies with undiminished ardour; but his recantation was so formal and without reservation, that prudence might have restrained him from bringing them unnecessarily before the world, and, more than all, his clerical persecutors. No decree had been issued against his telescope, his scientific discoveries, or the free exercise of his genius. He was simply forbidden to teach a doctrine deemed injurious to implicit belief in the Scriptures, and to the Christian faith. Moreover, he was liable to the authority of a court which possessed the power of torture and of death by fire within its jurisdiction.

But his enthusiasm in the cause of science was irrepressible, and rendered him fearless as to consequences. Thus, before six years were past, he began to compose his "Cosmical System; or, Dialogues on the Two Greatest Systems of the World—the Ptolemean and the Copernican," a work, the concealed object of which was to establish the very opinions he had promised, under threats, to abandon. Three speakers, Sagrado, Salviatus, and Simplicius, debate on the merits of those systems, and thus Galileo hoped that by this indirect mode of diffusion he might get the better of the Holy Office. So the work was printed at Florence in 1632.

A year elapsed before the Fathers of the Holy Office gave any indication of an attempt to open their prosecution again. Nor, to do them justice, did they seem to care for doing so, until they saw that those tenets, to them so obnoxious, were spreading fast, in consequence of the publication of the imaginary dialogues. A careful examination soon proved the work to be a deliberate violation of the injunctions laid upon Galileo, whom they summoned once more before their tribunal in 1633, and the poor old man, now in his seventieth year, was compelled to travel from Arcetri to Rome, at a time when the appliances for locomotion were not what they are now; and on his arrival he was committed immediately, like a criminal, to the chambers of the Fiscal of the Inquisition. The friendship and influence of the Grand Duke obtained a change for him, and he was permitted to reside in the palace of the Tuscan ambassador during the two months over which his trial extended. Examined on oath before that dread and mysterious tribunal, he candidly acknowledged that he was the author of the Dialogues, and that he had composed them in such a manner "that the arguments in favour of the Copernican system, though given as partly false, were yet managed in such a mode that they were more likely to confirm than overthrow its doctrines; but that this error, which was not intentional, arose from the natural desire of making an ingenious defence of false propositions and of opinions that had the semblance of probability."

Such was his simple confession. For defence he could produce only the certificate of Cardinal Bellarmin, which omitted all allusion to the non-teaching of the Copernican doctrines. This was deemed by the Holy Inquisition to be but an aggravation of the crime, and they proceeded to pronounce a sentence, or rather, under terror of death, to extort a confession perhaps one of the most memorable in the history of the human heart.

After solemnly invoking the name of our Saviour, they declared that Galilei Galileo had become a heretic by believing in a doctrine contrary to the Scripture, "that the sun was the centre of the earth's orbit, and did not move from east to west; and by defending, as probable, the opinion that the earth moved, and was not the centre of the world, and that he—the said Galileo—had thus incurred all the censures and penalties enacted by the Church against such offences; but that he should be absolved from these penalties, provided he abjured and cursed all the errors and heresies contained in the formulæ of the Church, which should be submitted to him; that he should be condemned to the prison of the Inquisition during pleasure, and that during the three following years he should recite the seven penitential psalms."

Seven cardinals subscribed this astonishing sentence on the 22nd of June, 1633.

Then Galileo, worn with age, weary of the mental torture to which he had been subjected, and weakened by the influences around him, signed an abjuration, alike humiliating to himself, and degrading to philosophy. In his old age, with hair and beard as white as snow, bent on his knees, with his right hand resting on the New Testament, Galileo avowed that he abandoned, "as false and heretical, the doctrine of the earth's motion, and of the sun's immobility, and pledged himself to denounce to the Holy Office any other person who was suspected of such heresy."

It seemed as if the hand of Fate was over the unhappy Galileo now. Freed from the Inquisition and all its terrors, he only returned home to find calamity there, for his favourite daughter had been seized with an illness which soon ended in death. Intense melancholy, hernia, palpitation of the heart, and a perfect loss of appetite now fell upon himself, all of which was believed by his enemies to be the curse of God upon him as a heretic; and though he prayed for leave, impoverished though he was, to visit Florence in search of medical advice, it was refused him by the Holy Office, which had special supervision of his movements. The Pope, however, took mercy upon him, and in 1638 he was permitted to visit the Tuscan capital, in care of his friend Padre Castelli and a familiar of the Inquisition, an indulgence soon withdrawn, and he was ordered to return to Arcetri. His eyesight had now begun to fail him, and in the year 1637 he became stone-blind.

Even the Inquisitors now had mercy on the patriarch of science, aged, blind, bereaved, impoverished, and crushed in spirit. They permitted him to have the society of his friends, who now thronged about him to express their admiration and sympathy. Among those who came thus were the reigning Grand Duke of Tuscany, Pierre Gassendi, the great French philosopher and mathematician, John Milton, the author of "Paradise Lost," Diodati, and many more. His sense of hearing soon followed his sight; but the brilliant faculties of his mind remained unimpaired; and it was while occupied in experiments, and in considering the force of percussion, that a fever and palpitation of the heart fell upon him, and he expired on the 8th of January, 1642.

PRINCIPLES OF DESIGN.—XIII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

HAVING considered furniture, the formation of which requires a knowledge of construction, or of what we may term structural art, we pass on to notice principles involved in the decoration of surfaces, or in "surface decoration," as it is usually called. Under this head, we commence by considering how rooms should be decorated; yet, in so doing, we are met at the very outset with a great difficulty, as the nature of the decoration of a room should be determined by the character of its architecture. My difficulty rests here. How am I to tell you what is the just decoration for a room, when the suitability of the decoration is often dependent upon even structural and ornamental details; and when, in all cases, the character of the decoration should be in harmony with the character of the architecture? Broadly, if a building is in the Gothic style, all that it contains in the way of decoration, and of furniture also, should be Gothic. If the building is Greek, the decorations and furniture should be Greek. If the building is Italian, all its decorations and furniture should be Italian, and so on.

But there are further requirements. Each term that I have now used, as expressive of a style of architecture, is more or less generic in character, and is therefore too broad for general use. What is usually termed Gothic architecture, is a group of styles having common origin and resemblances, known to the architect as the Semi-Norman or Transition style, which occurred in the twelfth century under Henry II. (it was at this time that the pointed arch was first employed). The Early English, which was developed in the end of the twelfth and early part of the thirteenth century, under Richard I., John, and Henry III.; the Decorated, which occurred at the end of the thirteenth, and early portion of the fourteenth century, under Edward I., Edward II., and Edward III.; the Perpendicular, which occurred at the latter part of the fourteenth, and through the greater portion of the fifteenth century, under Richard II., Henry IV., V. and VI., Edward IV. and V., and Richard III.; and, lastly, the Tudor, which occurred at the end of the fifteenth, and the beginning of the sixteenth century, under Henry VII. and Henry VIII. All these styles are properly spoken of as one, and are expressed by the one term—Gothic. It is so also, to an extent, with the Greek, Roman, and Italian styles, for each of these appear in various modifications of character, but into such details we will not enter; it must suffice to notice that the character of the decoration must be not only broadly in the style of the architecture of that building which it is intended to beautify, but it must be similar in nature to the ornament produced at precisely the same date as the architecture which has been employed for the building.

It must not be supposed that I am an advocate of reproducing works, or even styles of architecture, such as were created in times gone by, for I am not. The peoples of past ages carefully sought to ascertain their wants—the wants resulting from climate—the wants resulting from the nature of their religion—the wants resulting from social arrangements—the wants imposed by the building material at command. We, on the contrary, look at a hundred old buildings, and without considering our wants, as differing from those of our forefathers, take a bit from one and a bit from another, or we reproduce one almost as it stands, and thus we bungle on, instead of ever seeking to raise such buildings as are in all respects suited to our modern requirements.

Things are, however, much better in this respect than they were. Bold men are dealing with the Gothic style in its various forms. Scott, Burgess, Street, and many others, are venturing to alter it; and thus, while it is losing old characteristics, and is acquiring new elements, it is already assuming a character which has nobility of expression, truthfulness of structure, and suitability to our special requirements. In time to come, further changes will doubtless be made; and thus the style which arose as an imitation of the past, will have become new, through constantly departing from the original type, and as constantly adopting new elements.

I have said that the decoration of a building should be brought about by the employment of such ornament as was, in time past, associated with the particular form of architecture employed in the building to be decorated, if a precisely similar form of architecture previously existed. Let not the ornament, however, be a mere servile imitation of what has gone before, but let the designer study the ornament of bygone ages till he understands and *feels* its spirit, and then let him strive to produce new forms and new combinations in the spirit of the ornament of the past.

This must also be carefully noted—that the ornament of a particular period does not consist merely of the forms employed in the architecture, drawn in colour on the wall, or the ceiling, as the case may be. The particular form of ornament used in association with some forms of Gothic architecture was very different in character from what we might expect from the nature of the architecture itself, and did not to any extent consist of flatly-treated crockets, gable ends, trefoils, cinquefoils, etc. The ornament of the past must be studied in its purity, and not from those wretched attempts at the production of Gothic decoration which we often see.

In what we may call the typical English house of the present day there is really no architecture, and if such a building is to be decorated it is as legitimate to employ one style of ornamentation as another. In such a case I should choose a style which has no very marked features—which is not strongly Greek, or strongly Gothic, or strongly Italian; and if there is the necessary ability I should say try and produce ornaments having novelty of character, and yet acknowledging (showing your knowledge of) the good qualities of all styles that are past. If this is attempted, care must be exercised in order to avoid getting a mere combination of elements from various styles as one ornament. Nothing can be worse than to see a bit of Greek, a fragment of Egyptian, an Alhambraic scroll, a Gothic flower, and an Italian husk, associated together as one ornament; such an ornamental composition would be detestable. What I recommend is the production of new forms; but the new composition may have the vigour of the best Gothic ornament, the severity of Egyptian, the intricacy of the Persian, the gorgeousness of the Alhambra, and so on, only it must not imitate in detail the various styles of the past.

Now as to the decoration of a room. If one part only can be decorated, let that one part be the ceiling. Nothing appears to me more strange than that our ceilings, which can be properly seen, are usually white in middle-class houses, while the walls, which are always in part hidden, and even the floor, on which we tread, should have colour and pattern applied to them; and of this I am certain, that, considered from a decorative point of view, our ordinary treatment is wrong.*

We glory in a clear blue sky overhead, and we speak of the sky as increasing in beauty as it becomes deeper and deeper in tint. Thus the depth of the tint of the Italian sky is familiar to us all. Why, then, make our ceilings white? I often ask this question, and am told that the whiteness renders the ceiling almost invisible; hence it is preferred. This idea is very absurd; first, because blue is the most ethereal and most distant of all colours (see Chap. V., page 191); and, second, do we not build a house with the view of procuring shelter? hence why do we seek to realise the feeling that we are without a covering over our heads? We only like a white ceiling because we have been accustomed to such from infancy, and because we have been taught to regard a clean white ceiling as all that is to be desired. I knew a Yorkshire lady who, upon being asked by her husband whether she would like the drawing-room ceiling decorated, replied that she thought not, as she could then have it re-whitewashed every year. The idea was clean certainly. Blue, I have said, is ethereal in character; it is so, and may become exceedingly so if of medium depth and of a grey

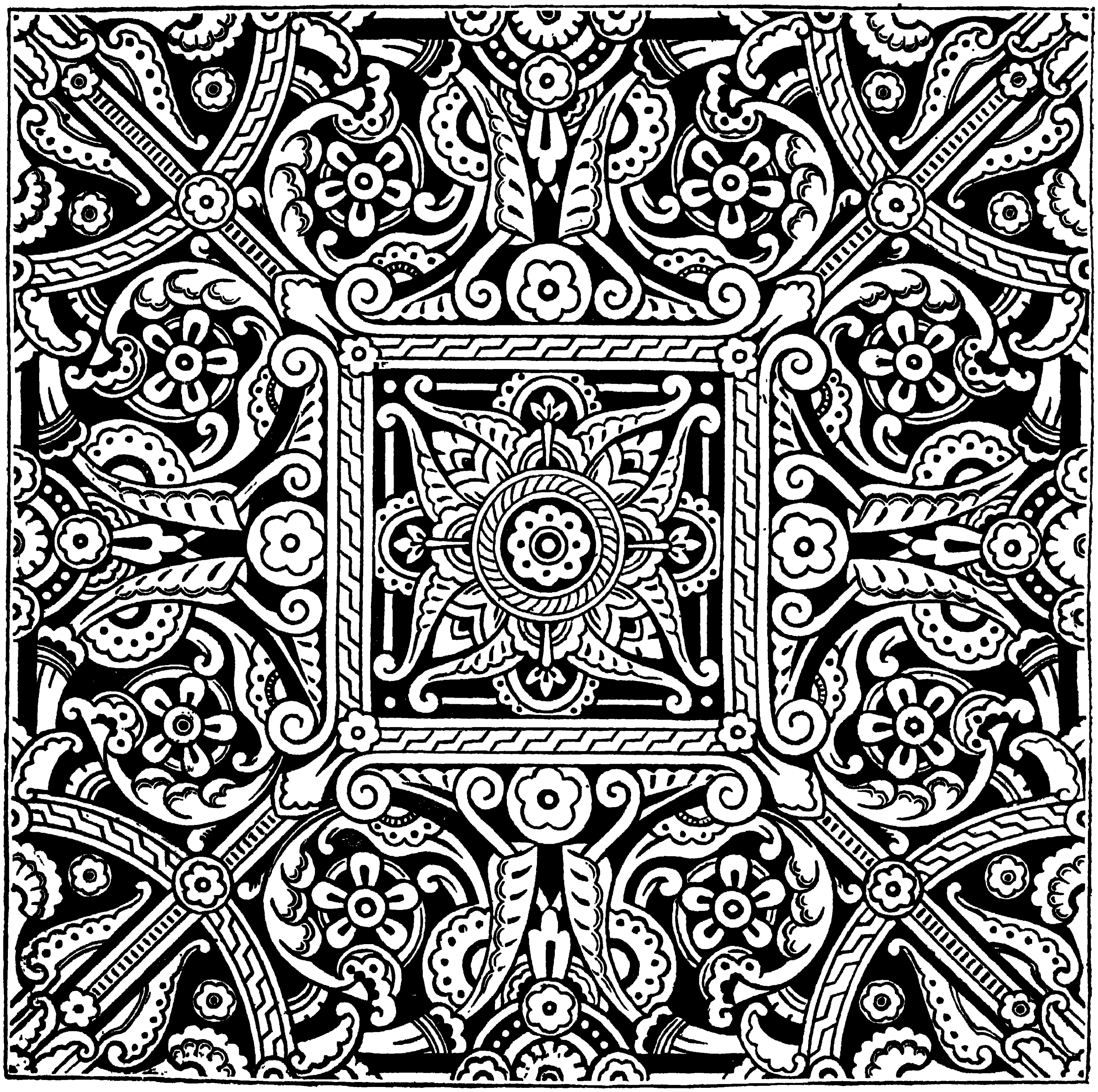


Fig. 39.—DESIGN FOR THE ORNAMENTATION OF A CEILING.

hue; hence, if a mere atmospheric effect was sought, it would be desirable that this colour be used on the ceiling rather than white. But, as we have just said, invisibility of the ceiling is absurd, as it is our protection from the weather. Further, the ceiling may become an object of great beauty, and it can be seen as a whole. Why then neglect the opportunity of arranging a beautiful object when there is no reason to the contrary? We like a beautiful coloured vase, or, if we do not, we can have it whitewashed, or even dispense with it altogether. We like beautiful walls, or we would have them whitewashed also; indeed, we like our surroundings generally to be beautiful. Why not, then, have beautiful ceilings, especially as they can be seen complete, while the wall is in part hidden by furniture and pictures?

I will suppose that we have an ordinary room to deal with. First, take away the wretched plaster ornament in the centre of the ceiling, for it is sure to be bad. There is not one such ornament out of a thousand that can be so treated as to make the ceiling look as well as it would do without it. Now place all over the ceiling a pattern which repeats equally in all directions (as Fig. 39), and let this pattern be in blue (of any depth) and white, or in blue (of any depth) and cream colour, and it is sure to look well (the blue being the ground, and the cream colour or white the ornament).

Simple patterns in cream colour on blue ground, but having a strong black outline, also look well; and these might be prepared in paper, and hung on the ceiling as common paper-hangings, if cheapness is essential. Gold ornaments on a deep blue ground, with black outline, also look rich and effective. These are all, however, simple treatments, for any amount of colour may be used on a ceiling, provided the colours are employed in very small masses, and are perfectly mingled, so that the effect produced is that of a rich coloured bloom (see Chap. VII., Vol. I., p. 229). A ceiling should be beautiful, and should also be manifest; but if it must be somewhat indistinct, in order that the caprices of the ignorant be humoured, let the pattern be in middle-tint or pale blue and white only.

I like to see the ceiling of a room covered all over with a suitable pattern, but I do not at all object to a large central ornament only, or to a centre ornament and corners; especially if the cornice is heavy, so as to give compensating weights in the margin. I have recently designed and seen "carried out" one or two centre ornaments for drawing-rooms, which ornaments were twenty-one feet in diameter. A centre ornament, if properly treated, may be very large without looking heavy; it may, indeed, extend at least two-thirds of the way from the centre to the margin of the ceiling.

If the ceiling is flat all ornament placed upon it must not only be flat also, but must not fictitiously represent relief, for no shaded ornament can be pleasant when placed as the decoration of an architectural surface.

TECHNICAL DRAWING.—XXX.

THE STEAM-ENGINE.

The modern steam-engine owes its origin and development to the united genius and persevering industry of many inventors. Its influences upon the civilisation and comforts of the human race are incalculable, and it may be said with truth that no other mechanical contrivance has had so large a share in the unprecedented advancement that has taken place through the world during the present century. Even the printing-press, which ranks second, would never have accomplished so much without the untiring power of the steam-engine to drive it.

Like other great discoveries, its origin seems lost in obscurity. More than 2,000 years ago Hero of Alexandria described a re-action steam-engine, which is now used as a sort of toy; but the first to make a practical use of the elastic force of steam were the priests in the heathen temples, and the more scientific warriors of ancient story. They made hollow images of brass, idols or dragons, and filled them with water or spirits. Steam or vapour issuing from the mouth or nostrils seemed to indicate to the idol-worshippers the wrath of their gods, and the fiery dragons served to terrify an ignorant enemy.

The first man of whom any authentic record exists as having dimly dreamed of the latent power of steam, was Solomon de Caux, about the year 1614. His machine was a sort of fountain worked by steam; but the only result of his ingenuity was his own incarceration in the Bicêtre, the Paris lunatic asylum, by Cardinal Richelieu, the powerful minister of Louis XIV. Here he was visited by the Marquis of Worcester, who at length brought out his "Fire Water Work," a rude pumping-engine, and declared it to be an admirable and most forcible instrument of propulsion; but as the marquis was in disfavour, and suspected of being a madman, his machine attracted little public notice, and was never practically adopted. These experiments and others prepared the way for, and excited the notice of, future inventors, and Thomas Savery's improvements were quickly followed by Newcomen's engine, which contained the germ of the present Cornish pumping-engine. Its valves were moved by boys, and one of them, named Humphrey Potter, desiring to leave his irksome task for play, arranged cords attached to the engine so as to move the valves. This was a great improvement, and reflected much credit upon the youthful inventor. Brindley, Smeaton, and others made further progress; but the greatest improvements were made by James Watt, who is justly styled the father of the modern steam-engine.

In partnership with Matthew Boulton, of Soho, near Birmingham, Watt rapidly made numerous changes in Newcomen's engine, and brought the Cornish pumping-engine to the state in which it now exists. He also arranged the beam-engine to drive factories, and made many other minor improvements.

In 1802 Captain Trevithick patented the first locomotive, and several were used to drag colliery trucks in South Wales; but they were heavy and slow, and altogether inefficient for passenger traffic. After many alterations and improvements on the original idea, several different types of locomotive were invented, and in 1830 Stephenson's engine, the "Rocket," was worked most successfully on the Liverpool and Manchester Railway, and it contained the same general features as the locomotives now in use all over the civilised world.

Meanwhile engineers were not idle in their application of the same potent agency to the propulsion of ships. The first to realise and carry out this idea seems to have been a Spanish captain, Blasco de Garay, who in 1543 induced the Emperor Charles V. to allow him to put his idea into practice. No trustworthy accounts exist, but it is stated that his ship was moved by paddles, and had a steam-boiler on board. The ship seems to have moved at about four miles an hour in the harbour of Barcelona, but was not developed further.

In the beginning of the present century, Robert Fulton and others made several steam-ships, but the first which left England for America was the *Sirius* in 1838, followed quickly by the *Great Western*, and now there is hardly a sea or river where steam-ships are not seen.

Such, then, in brief outline, has been the history of this marvellous invention. Those only who have made the giant strides in its construction have their names and deeds known to fame, but hosts of inventors have emulated their exertions, and we see the results in the modern steam-engine.

Several distinct types of steam-engine are known, but unceasing change is still going on in matters of detail. It would be altogether foreign to the purpose of the present subject to enter into these matters, and two types only have been selected for illustration.

One, the vertical engine, as generally employed for marine purposes. The other, most universally known for stationary use, and the best for smaller sizes, namely, the horizontal high-pressure engine. This last forms the subject of the present lesson, and is preceded by detailed drawings of its various parts.

Before describing the details of this engine, it will be well to consider the subject of designing machinery. It should never be forgotten that art ought to have its full share as well as science, and if any parts seem disproportioned to an educated eye, it is a sure sign that they need correcting in some way. As with a building, so with a machine, each should have its own peculiar beauty; and there is as much art and good taste required for the design of an engine or machine as in planning a house or palace. But the forms suitable for a *stone* building are not proper for *iron* machinery: for example, the older side-lever marine engines were made strong and massive, but carved and ornamented like a Gothic building, with pointed arches, window-frames, mullions, capitals, etc.; while pedestals and shafts arranged upon this structure, with an utter disregard to position or fitness, gave to the whole thing a stupendous incongruity. These strange mixtures of styles were, fortunately, as a rule, buried in the holds of ships; but they furnish most admirable lessons of what every designer of machinery should avoid. The true beauty of design in engineering design follows the same rules as those which render a group of statuary pleasing to the eye; and the graceful forms of a well-designed machine impress the mind with a sense of beauty, of fitness, and of power.

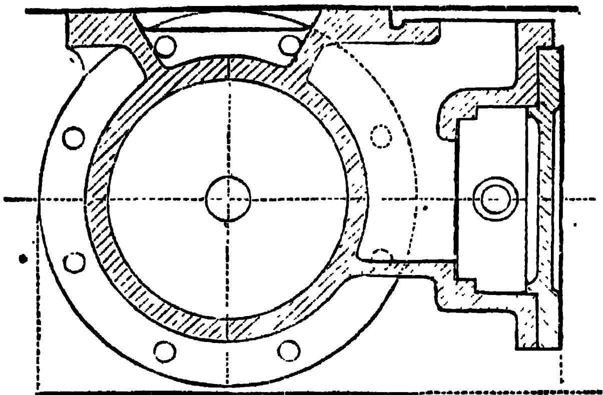


Fig. 277.

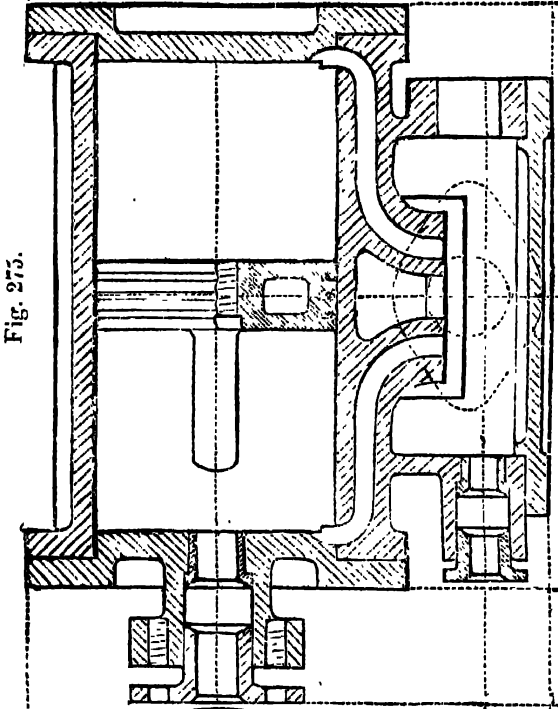


Fig. 275.

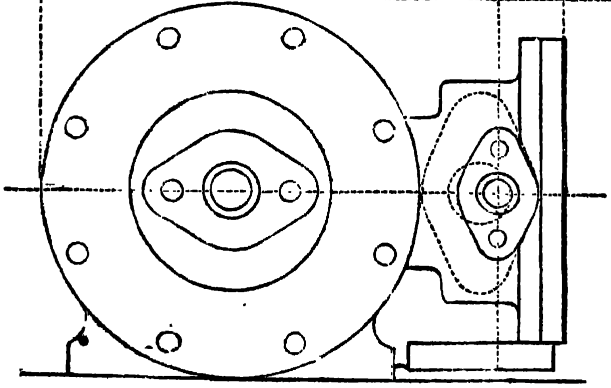


Fig. 278.

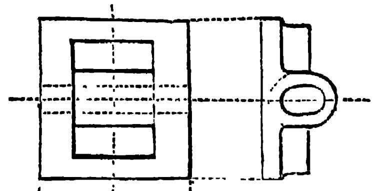


Fig. 280. Fig. 281.

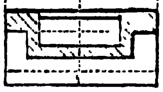


Fig. 279.

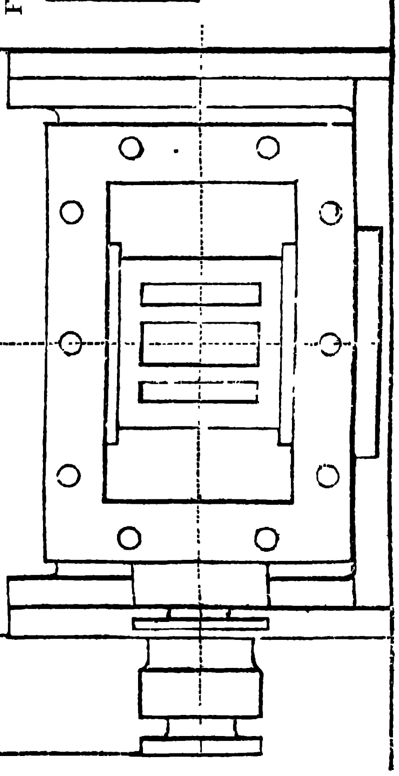


Fig. 276.

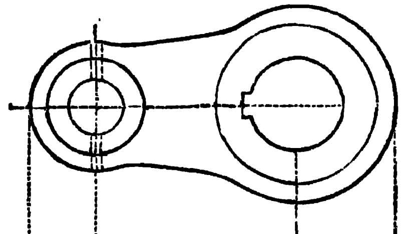


Fig. 283.

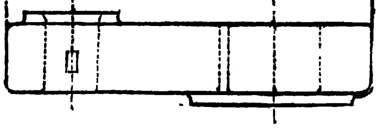


Fig. 282.

These remarks apply in favour of all the machines illustrated in this work, especially to those of Sir Joseph Whitworth, and to the drawings of steam-engines now under notice.

A great error is frequently committed by designers in attempting to pack their machines into the smallest possible compass. The inconvenience of such an arrangement is very great; for the parts are with difficulty cleaned, cannot be seen or oiled, and therefore soon get out of repair. A very slight experience in machinery furnishes many illustrations of this defect, and it is peculiarly common with steam-engines. Cases exist, as on board ship, where economy of space is almost as important as economy of fuel, and there close packing is unavoidable, but in the majority of instances close packing of working parts is an evil to be avoided, and not an object to be sought. Another important consideration is the constructive detail, and it is here that experience becomes requisite, and any mere theoretical education fails altogether. All parts of an engine or machine ought to fit into their places without removing those already fixed, and not, for example, require an entire framework to be removed in order to get in a shaft or wheel. The design should follow construction, and the machine be built up in imagination before being made in the workshop. Thus unsuitable arrangements may be detected, and the great expense of altering work already made avoided. Every part of a machine ought to possess equal strength, except in such cases as clay-mills, where accident or mischief may give a far heavier strain than the parts are calculated to endure. Where such circumstances exist, it is desirable to have a cheap simple casting made, weaker than the rest of the mill, so that fracture shall take place in it rather than in the more costly parts.

The knowledge of proper proportions cannot be perfectly acquired otherwise than by observation and experience, and it is excellent practice to copy good machinery drawings, or the machines themselves. The strength of materials forms a useful basis for this knowledge, but so great a margin is necessary to allow for irregular strains and ensure rigidity of the parts, that calculations of theoretical strength in machines, although interesting and useful, are, as a rule, exceedingly difficult in their application, and practical experience is found absolutely necessary.

Cost of construction is affected much more by design than workmanship, and a machine well designed and constructed is invariably cheaper than one badly designed and made. Mere cheapness is a thing to be avoided, and simplicity should take its place. It is the duty of the designer to arrange the parts or details so that they may be easily and cheaply made, while effectually answering their intended purposes: the amount of labour he may save is much more than can ever be gained by careless workmanship, to say nothing of the more satisfactory results.

GENERAL DESCRIPTION OF ENGINE DETAILS.

Scale, one inch and a half to the foot.

Fig. 275 is a horizontal section of the cylinder and valve-box, showing the steam-ports, passages, and many other details. Fig. 276 is a side elevation, with the front view of steam-ports, the valve-box cover being removed; and Fig. 277 is a cross-section through the middle of cylinder, at right angles to its axis. Fig. 278 is a front elevation to show the cover, bolt-holes, and glands. Inside the cylinder is a piston, shown in section and elevation, known as Ramsbotham's Patent. The packing consists of several thin steel rings, held in grooves in the cast-iron block, while steam, admitted behind them, allows their own elasticity to keep the rings against the smooth inner surface of the cylinder, and so retain a steam-tight joint.

The inlet and outlet ports for steam are clearly shown by Figs. 275 and 277, the latter being made of larger dimensions, so as to carry away the greater volume of expended steam after it has driven the piston. The object of having the exhaust-pipe taken from below is to carry off all the condensed water from the cylinder.

Figs. 279, 280, and 281 are three views of the slide-valve, called a short D-valve, from its appearance being originally like that letter. This valve covers over the ports, and being moved by an eccentric (shown in the next lesson), it admits and exhausts steam at proper intervals.

The crank (Figs. 282 and 283) is shown in side and front view; it fits upon the end of the main shaft, and is the means of converting rectilinear into rotary movements.

APPLIED MECHANICS.—XI.

BY ROBERT STAWELL BALL, M.A.,

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THE TURNING-LATHE AND THE SLIDE-REST.

THE turning-lathe is the most important tool used in giving definite form to masses of iron or other substances. It enables us to produce with perfect accuracy any surface of revolution. The nature of a surface of revolution will be understood from Fig. 1 in the opposite page. A curve, A Q P B, is conceived to revolve about the line A B. It describes a surface, the nature of which depends upon the form of the curve A Q P B. If this were a semicircle, as in Fig. 2, the surface traced out is that of a sphere. If A Q P B formed a rectangle, as in Fig. 3, then the line P Q produces a cylinder, while A Q and B P form the circles which are at the ends of the cylinder. If A Q B form a triangle, as in Fig. 4, the line B Q traces out a cone, and A Q forms the circle at the base of the cone. The axis A B, about which the cone revolves, may be entirely independent of the arm, as, for example, in Fig. 5, in which the circle P Q revolves around the line A B. In this case the circle traces out a ring. It will be seen from these simple examples that a great multitude of different forms are surfaces of revolution. In fact, the majority of symmetrical forms are of this class.

All surfaces of revolution have one property in common which arises from the nature of their mode of generation. We shall fix our attention upon the point P (Fig. 1). Let fall a perpendicular, P R, from P upon the axis of revolution, A B. The line P R remains of constant length when the curve rotates about the axis A B. The point P must therefore describe the circumference of a circle of which R is the centre and P R the radius. The same is obviously true for every other point along the curve A Q P B. It follows, therefore, that the entire surface of revolution is produced by each point in the curve describing a circle. We may state the same property in slightly different language. Suppose a plane perpendicular to the axis A B to be drawn, then the intersection of this plane with the surface of revolution is always a circle.

To form, therefore, a surface of revolution from a piece of material, it is only necessary to produce a series of circles the centres of which lie upon the axis of revolution. If these circles have equal radii, then the surface of revolution is a cylinder (Fig. 3). If the radii increase uniformly from one end of the axis to the other, then the surface is a cone (Fig. 4).

The turning-lathe is a tool by which circles can be produced, and since the radii of the circles can be disposed at pleasure, the turning-lathe provides the means of producing surfaces of revolution. If we remember how important are the forms of the cylinder, the cone, and the sphere, not to mention the other surfaces of revolution, we shall be able to understand the vast utility of the lathe in the arts of construction.

The simplest form of the turning-lathe is shown in Fig. 6. This lathe is intended to be worked by the foot, but in principle is the same as if intended to be worked by a steam-engine or other source of power.

The action of the crank will be understood by Fig. 7. C E is the foot-board; this turns around a centre at C, and at the point F the pressure of the foot is applied. Thus the foot-board is a lever of the third order, of which C is the fulcrum, E the point of application of the resistance, and F the point of application of the power. It follows from the principle of the lever, which we have already explained, that the power at F is to the load at E in the ratio of the two lines C E and C F. If F be applied midway between C and E, as is usual in the treadle of a lathe, the power at E will be half the power at F. There is, therefore, a diminution of power for the purpose of increased convenience in the mode of working. The power is transmitted from the foot-board, C E, to the crank, O D, by means of the connecting-rod, E D. As the foot-board oscillates to and fro, the crank performs complete revolutions. It is obvious that in a foot-lathe the power can only be applied during the descent of the foot-board; the power is therefore only transmitted to the axle at O during a portion of the revolution. In order to enable the work of the lathe to be performed continuously, some means must be devised by which the energy imparted to the machine during the descent of the foot-board shall be equalised throughout the entire rotation. For this purpose a heavy fly-wheel, shown at F (Fig. 6), is attached to the axle. As we have already explained, when treating of the punching-machine, energy can be stored up in the fly-wheel. By this means the impulsive action of the foot is moderated, and the energy which is stored up when the action is too great is sufficient to carry on the work of the lathe during that portion of the revolution when the power has ceased to act. In the figure two cranks and connecting-rods are shown; this is usual in long lathes, because it is desirable that the foot should always be near the connecting-rod.

The fly-wheel is called upon to perform another duty besides that of equalising the motion on the circumference of the wheel. At F three grooves will be seen; upon the centre groove is a band, which passes up to the bed of the lathe, and embraces a corresponding groove in the pulley shown at G. The object of this band is to transmit the motion from the axle A B to the work upon which the lathe is engaged. The action of the band will be understood from Fig. 8. In this figure A and C are two wheels which are embraced by the same band. Let us suppose that the wheel A is revolving in the direction shown by the arrows. If the band be properly tightened it will be impossible for the wheel to revolve without drawing the band towards it upon the one side and allowing it to pass away upon the other, as shown by the direction of the arrows. The motion of the band arises from the friction between the band and the wheel; this friction is so large that it is impossible for the band to slip unless the resistance opposed by the work be too large. Precisely as the wheel A makes the band to move, so the wheel C is moved by the band. It will be evident from an inspection of the arrow-heads that the wheel C is made to revolve in the same direction as the wheel A. Had A and C been toothed wheels, geared one into the other so that the revolution of A caused the revolution of C, C would have rotated in the opposite direction to the rotation of A.

It is easy to see that the velocities with which the wheels revolve are in the inverse proportion of their radii. When the wheel A has performed one revolution it will have delivered a length of the band equal to its circumference to the wheel C. Therefore C will have to perform as many revolutions as the length of its circumference is contained in the circumference of A. Therefore the velocities must be inversely proportional to the circumferences—that is, inversely proportional to the radii. If, for example, the large wheel A were ten times as great as C, and if A revolved once in a second, C will revolve ten times in a second.

The wheel F, in Fig. 6, thus serves not only as a fly-wheel, but also for the purpose of increasing the velocity of revolution, as it would be impossible by the action of the foot to give the work a velocity so great as is required for some kinds of work. It will be noticed that there are three grooves on the wheel F, and three corresponding grooves in the wheel G. The magnitudes of these grooves are so proportioned that the same band will apply to each pair. Thus, when the greatest speed is required for the work, the band is placed upon the largest groove on F and the smallest groove on G; when a medium speed is required, the band is placed upon the centre groove in each wheel; and when the lowest speed is required, the band is placed upon the smallest groove of F and the largest groove of G.

As bands occur so often in machinery, and as we shall have occasion to refer to them subsequently in these lessons, it will be well to investigate the general formula for determining the proper length of the band which shall be employed when we know the dimensions of the pulleys and the distance between their centres.

Let the radius, A B, of the larger pulley be R, and C D be R′, and let d be the distance, A C, between the centres.

Let fall from C the perpendicular, C P, upon the radius, A B. The length of the band is composed of four portions, namely, the two portions of the common tangents intercepted between the circles, and the two portions of the circles which are embraced by the band. The lengths of these portions have to be found separately, and their sum will then give the required length of the band.

The common tangent, D B, is equal to C P; but since A C P is a right-angled triangle—

$$AP^2 + CP^2 = AC^2.$$

But $AP = AB - BP = AB - CD$, since $PBDC$ is a parallelogram;

$$\therefore\ AP^2 = (AB - CD)^2 = (R - R')^2.$$

Hence we have—

$$(R - R')^2 + CP^2 = AC^2 = d^2;$$
$$\therefore\ CP^2 = d^2 - (R - R')^2;$$
$$\therefore\ CP = \sqrt{d^2 - (R - R')^2}.$$

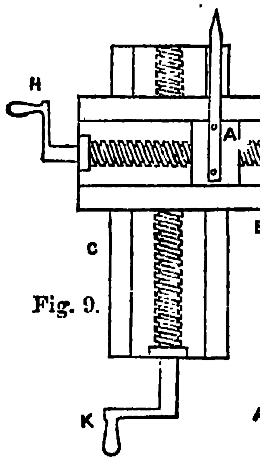

Fig. 9.

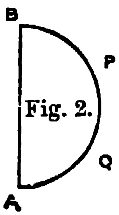

Fig. 2.

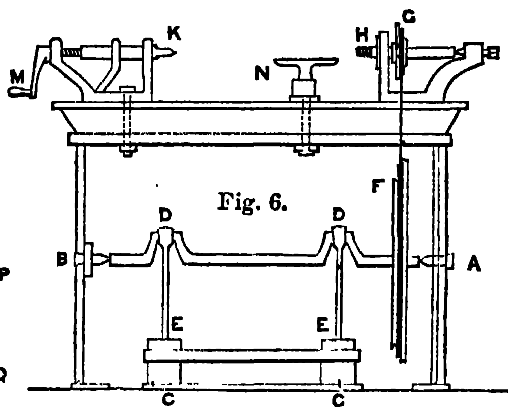

Fig. 6.

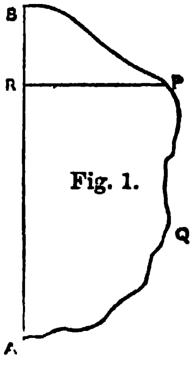

Fig. 1.

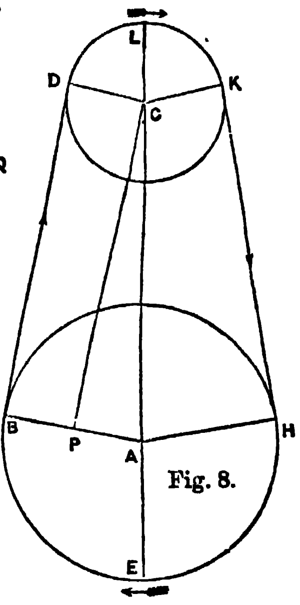

Fig. 8.

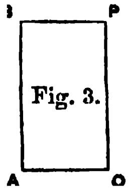

Fig. 3.

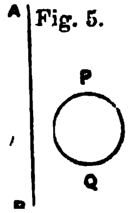

Fig. 5.

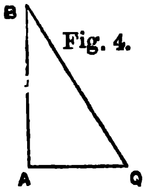

Fig. 4.

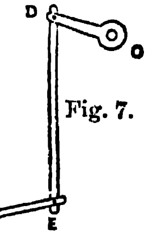

Fig. 7.

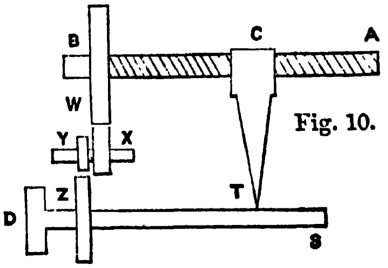

Fig. 10.

Hence the length of the common tangent is expressed in terms of the radii and of the distance between the centres.

To find the length of the part embracing the circle, it will be necessary to compute the angle B A C.

$$\text{Cos. } BAC = \frac{AP}{AC} = \frac{R - R'}{d}.$$

Hence, by reference to a trigonometrical table, the value of the angle B A C can be found expressed in degrees.

Since the arc of a circle is proportional to the angle it subtends at the centre, the length, B E H, must be to the whole circumference in the proportion which the angle subtended by B E H bears to four right angles. The angle subtended by B E H is equal to four right angles, minus the angle B A H, and it is evident that the line A C bisects the angle B A H, and that, therefore, the angle B A H is equal to double the angle B A C, which we have already determined. We have, therefore, the following proportion:—

$$\text{arc } BEH : \text{circumference} :: 360^\circ - 2 \times BAC : 360^\circ;$$

but the whole circumference is $\frac{44}{7}R$.

$$\text{arc } BEH = \frac{360 - 2 \times BAC}{360} \times \frac{44}{7}R.$$

We can also find the length of the arc, D L K, upon the smaller circle.

The angle D C L is equal to the angle B A C, since the line C D is parallel to A B, and therefore the arc D L K is found by the following proportion:—

$$\text{arc DLK} : \frac{44}{7}\text{R}' :: 2 \times \text{BAC} : 360;$$

$$\therefore \text{arc DLK} = \frac{2 \times \text{BAC}}{360} \times \frac{44}{7}\text{R}'.$$

Adding, therefore, these two lengths to double the length of the common tangent, the total length of the band becomes known.

It is also easy from the same principles to ascertain the proper magnitude of the grooves in the wheels, in order that the same band shall be applicable to every pair.

By means of the band the pulley G, on what is called the "mandril" of the lathe, is made to turn rapidly: attached to the mandril is a screw, H. This screw does not itself generally support the work: it bears what is called a "chuck," in which the work is held. The chucks used are of very varied forms, depending upon the character of the work upon which the lathe is engaged. It may be said, in general, that a chuck is a means of conveniently attaching the work to the mandril, so as to make the work partake of the rotation of the mandril. At the opposite end of the bed of the lathe is a point, K: this point is capable of being brought forward by a screw turned by a handle, M: this point should lie exactly in the prolongation of the axis of the mandril. The work is thus held securely between the point and the chuck. For short pieces of work, however, the point is often found not to be necessary; but when the work has considerable length, it would be impossible without the point to secure it so firmly in the chuck that the application of the cutting-tool should not cause it to swerve a little from the proper position.

In ordinary tools, such as the saw, chisel, or plane, the work remains at rest while the tool is moved. In the lathe, however, it is the work which is moved, while the tool remains at rest. This is the case in the more usual applications of the lathe, but occasionally, particularly in ornamental turning, a movable tool is employed. This we shall not delay to consider, as we wish to treat principally of the practical applications of the lathe, rather than of the more fancy uses to which it is occasionally put.

In the lathe shown in Fig. 6, the tool is held in the hands of the workman; the rest N is placed near the work: and while the edge of the tool is in action, the shank is held firmly upon the rest. Since the work revolves rapidly about an axis, it follows that when the point of the tool is applied it must trace out an exact circle upon the work; and since the radius of this circle can be of any magnitude, within reasonable limits, and also since the tool can be moved along the work, it follows that any figure of revolution, as already defined, can be produced by the lathe.

One of the most important uses to which the lathe is applied is the production of a perfect cylinder. The piston-rod of a large marine engine, for example, should be as nearly as possible perfectly cylindrical. The inside of the steam cylinder should also be perfectly uniform if leakage is to be avoided. Now, to produce a cylinder with the lathe we have shown in Fig. 6, or with a power-lathe adapted to the magnitude of the work, upon the same principle, is a work of no little difficulty, and demanding great skill on the part of the workman. It is extremely difficult, nay impossible, for the most skilled mechanic to hold and move his tool with such precision that the figure he produces shall not have a section slightly larger or smaller in some places than others, and thus making his work deviate from the truly cylindrical form. To meet this difficulty the slide-rest was devised, which, holding the tool with perfect steadiness, and moving it with perfect regularity, enables the lathe to turn out a profusion of perfect forms, with the minimum amount of skilled attendance.

The slide-rest is really an iron hand which holds the tool and enables it to be turned towards the work, or from it, or moved parallel to the bed of the lathe, with facility and precision.

The character of the slide-rest will be understood from Fig. 9, which represents the essential features in a diagrammatic manner. T is the tool. This tool is firmly attached to a small stage, A, by means of screws. The stage, A, is mounted upon a slide, B, and by means of the handle shown at H, and the screw which is attached to it, and which works in a nut underneath A, the stage A can be moved to the right or left. Just as the stage A is mounted upon the slide B, so the slide B is itself mounted upon the slide C, the screws at C and B being at right angles to each other. It follows, therefore, that, by properly turning the handles H and K, the point of the tool can be placed in any required position in the plane, to which its movement is restricted.

The slide C is itself fastened to the bed of the lathe by a clamp, so that it can be secured in any position that may be required. If the screw B be placed parallel to the axis of the lathe, then, by turning the handle H, the point of the tool will be moved in a line parallel to the axis of the lathe, and will, therefore, turn a perfect cylinder. By turning the handle K at the end of each cut, the point of the tool may be advanced so as to be ready to take a fresh cut.

When the slide-rest had been invented, it was a natural step to make the lathe self-acting, so that the tool should be moved uniformly by the machine itself without the aid of the workman. This object is obtained by having a screw along the bed of the lathe; the slide C, instead of being clamped to the bed, is attached to a nut upon this screw, so that when the screw along the bed of the lathe is made to revolve, the slide-rest is carried with a perfectly uniform motion.

We shall conclude this account of the lathe and slide-rest by a short description of the principle of screw-cutting, which is one of the many important applications of the lathe.

The principle of the screw-cutting lathe is shown in Fig. 10. A leading screw, A B, which should be made with extreme care, runs along the bed of the lathe, and passes through a nut on the slide-rest C: the screw receives motion from the pulley D, which carries the band from the fly-wheel or from a neighbouring shaft, if the lathe be worked by steam power. D is on the mandril of the lathe, to which the work S, on which the screw is to be turned, is to be attached. The motion is conveyed from the pulley D to the screw A B, by the intervention of the train of wheels, Z, Y, X, W. These wheels are toothed, and upon them depends the pitch of the screw which is made. Let us suppose that the leading screw, A B, contains n threads to the inch, and that the numbers of teeth in the train of wheels are denoted by the numbers X, Y, Z, W; we shall be able to find the number of threads produced on the work.

When A B has made n revolutions, the tool T will have been moved one inch, therefore the number of revolutions that the work has made will be the number of threads the screw traced upon it contains in the inch. When the wheel W, which is fixed upon A B, has revolved n times, the wheel X has revolved

$$\frac{\text{W}}{\text{X}} n \text{ times.}$$

The wheel Y is on the same shaft as X, and turns with it, therefore Y makes one revolution for each revolution of X, and Z will make

$$\frac{\text{Y}}{\text{Z}}$$

revolutions for every revolution of Y. Hence it follows that for every n revolutions of A B the work S will revolve

$$n \cdot \frac{\text{W} \cdot \text{Y}}{\text{X} \cdot \text{Z}}$$

times, and that, therefore, this will represent the number of teeth to the inch on the screw which is produced.

Suppose, for example, the leading screw had two threads to an inch, and that we have a series of wheels containing 10, 15, 20, etc., up to 100 teeth, and then by tens up to 200, it is easy to select four which shall cut a thread of any required pitch. If a screw of eight threads be required, we have

$$8 = 2\,\frac{\text{WY}}{\text{XZ}},$$

$$\text{or } 4 = \frac{\text{WY}}{\text{XZ}};$$

therefore W = 100, X = 50, Y = 100, and Z = 50

will give one set of wheels, but numerous others would have answered equally well.

Suppose a screw of fifteen threads to the inch be required,

$$15 = 2\,\frac{\text{WY}}{\text{XZ}}.$$

W = 100, X = 20, Y = 60, Z = 40 would answer.

A small expenditure of ingenuity will enable trains to be selected which shall produce screws containing no entire number per inch. For example, to produce a screw four inches of which shall contain forty-five teeth, we have—

$$\frac{45}{4} = 2 \cdot \frac{WY}{XZ},$$

$$\text{or } \frac{WY}{XZ} = \frac{5 \times 9}{4 \times 2} = \frac{50 \times 90}{40 \times 20};$$

$\therefore$ W = 50, Y = 90, X = 40, Z = 20 will give the required result.

Had the leading screw contained any other number of threads to the inch the calculations would be equally easy.

VEGETABLE COMMERCIAL PRODUCTS.

XVIII.

TANNING MATERIALS (*continued*).

NUT-GALLS (*Quercus infectoria*).—This tree abounds in Asia Minor. The galls are excrescences upon the young twigs, produced by the punctures of an insect, a species of *Cynips*. The market is chiefly supplied from the ports of the Levant, whence they are called Aleppo galls. They contain much tannin and gallic acid, and are largely employed both in tanning and dyeing. We receive nut-galls from Turkey, Greece, the Ionian Islands, Hungary, and Sclavonia, *viâ* Vienna, Trieste, Leghorn, Genoa, and Marseilles. One kind, called the *knoppern*, is distinguished from the smooth gall-nuts by many angular and rough excrescences, as well as by having the essential principles in greater strength.

DIVI-DIVI (*Cæsalpinia coriaria*; natural order, *Leguminosæ*).—This tree is a native of the salt marshes of Curaçoa, Carthagena, and other places in South America. It furnishes in abundance a brown pod, about the size of that of the pea, but curved into the form of the letter S. This pod is very astringent, and therefore of great value in tanning. The Indian name, *divi-divi*, has been adopted by our merchants. It is not used alone, but is generally mixed with oak-bark and valonia. In 1851 more than 3,000 tons were imported.

CATECHU (*Acacia catechu*; natural order, *Leguminosæ*).—A thorny tree; a native of Hindostan. Catechu is procured by cutting the wood into chips, boiling them, and then straining the liquor, and evaporating it until it assumes the appearance and consistency of tar. This substance hardens as it cools, is formed into small squares, dried in the sun, and is then fit for market. Catechu contains a large proportion of tannin. Packed in mats, it is sent to this country in large quantities from India. Several varieties of it are known to merchants by the names of catechu, terra japonica, cutch, and gambier. Dissolved in water, it tans skins very rapidly—one pound of catechu being equivalent to seven or eight of oak bark; but the leather is not so durable or good as that which is more slowly prepared from oak-bark.

BETEL-NUT PALM (*Areca catechu*, L.) grows in most parts of the East Indies. The trunk is straight and slender, and from forty to fifty feet in height; the fruit is about the size and shape of a small egg, and the nut itself rather larger than a nutmeg, roundish-conical, and brown in colour.

The betel-nut furnishes an astringent extract, which constitutes one or more varieties of the catechu of commerce. But the principal consumption of the betel-nut is for chewing, in combination with the pepper leaf of the *Charica betel* and lime. For this purpose the nuts are divided into quarters, one of which, rolled in the pepper leaf and sprinkled with lime, forms the quantity generally used. This mixture gives a red tinge to the saliva, and seems to have some narcotic power. It is in general use as a masticatory amongst the natives of the East Indies, much the same as tobacco in other countries.

On persons who are unaccustomed to chewing this preparation it has a very unpleasant effect, for the drug causes giddiness and staggering, takes all the skin off the mouth and lips, and destroys for some time all sense of taste. But when all this has been overcome—and it requires no little perseverance to accomplish it—the taste is said to be agreeable, while its use is beneficial. Thus it is stated by Sir James Emerson Tennent, the author of a valuable work on Ceylon and the habits and customs of the Cingalese, that it furnishes these people, who are not meat-eaters, with an antacid, tonic, and carminative which are absolutely necessary to them to correct the effects of a purely vegetable diet.

PRACTICAL GEOMETRY APPLIED TO LINEAR DRAWING.—VIII.

THE following figures are given to assist students in drawing pitch circles of wheels working in gear with each other, and will be found most important in numerous constructions where curves are to touch each other or to merge out of straight lines. These, too, it will be found, have been and will be further worked out in the lessons in Technical Drawing.

To draw a circle of a given radius, D E, *which shall touch both sides of an angle,* A B C (Fig. 71).

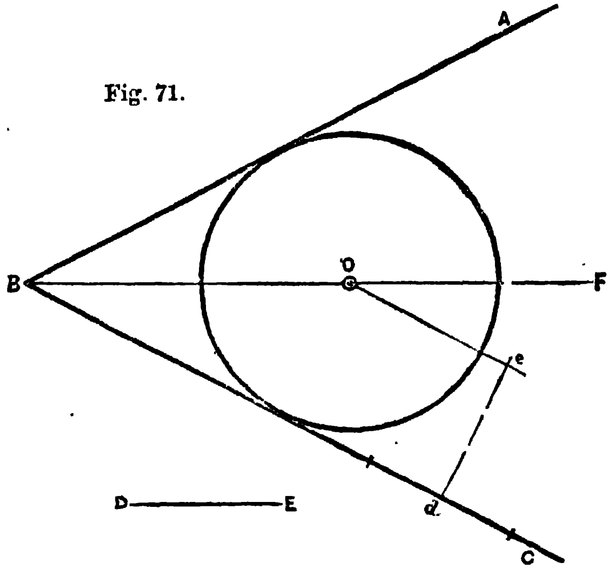

Fig. 71.

Bisect the angle by the line B F.

On either of the lines of the angle erect a perpendicular equal to the given radius D E—viz., *d e*.

From *e* draw a line parallel to B C, cutting the bisecting line in O.

From O, with the given radius, draw the circle, which will touch both the lines of the angle.

To draw a circle which shall touch both lines of an angle, and shall pass through a given point, P (Fig. 72).

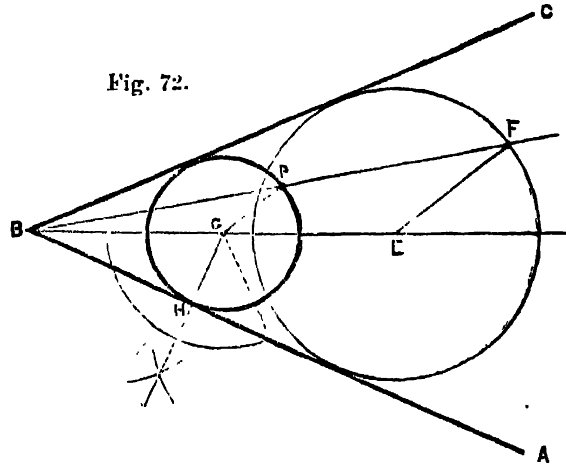

Fig. 72.

Let A B C be the given angle, and P the given point, through which the required circle is to pass.

Bisect the angle A B C by the line B D.

From any point in B D, as E, draw a circle, touching both lines forming the angle.

From B draw a line through P, cutting this circle in F.

Join F to E, the centre of the circle.

From P draw a line parallel to F E, cutting the bisecting line B D in the point G.

From G draw a line perpendicular to A B (by Fig. 6, Vol. I., page 64)—viz., G H.

Then, with radius G H, which will be found to be equal to

G P, describe a circle which will touch both lines forming the angle.

To draw a series of circles to touch each other and two lines not parallel (Fig. 73).

Produce A B and C D until they meet in E.

Bisect the angle A E C by E D′.

Draw the first circle at pleasure, and from its centre, X, draw a radius, X F, at right angles to E A.

From G draw G H perpendicular to E D′. From H, with radius H G, describe an arc cutting E A in I. Draw a line at I, perpendicular to A E, cutting E D′ in J.

From J, with radius J I, describe the next circle, cutting E D′ in K.

From K draw a line perpendicular to E D′, cutting E A in L.

From L, with radius L K, describe an arc cutting E A in M.

From M draw a line perpendicular to E A, cutting E D′ in N.

From N, with radius N M, describe a circle touching K, and cutting E D′ in O.

From O draw O P perpendicular to E D′.

From P, with radius P O, describe an arc cutting E A in Q.

From Q draw a line perpendicular to E A, cutting E D′ in R.

From R, with radius R Q, describe the next circle.

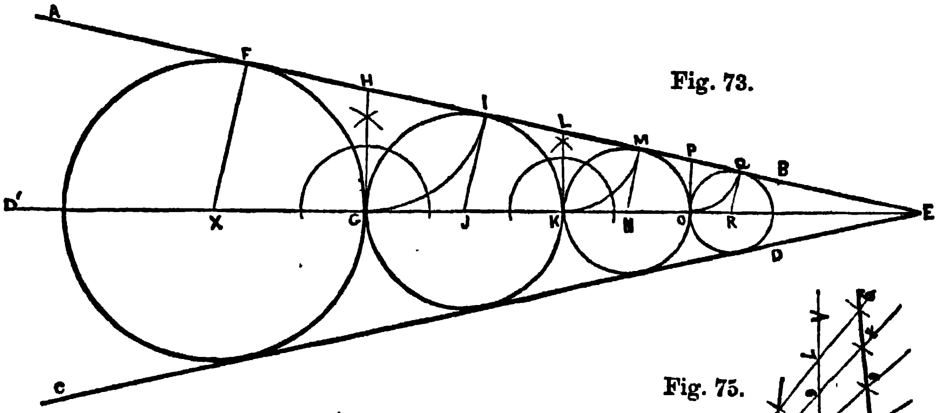

Fig. 73.

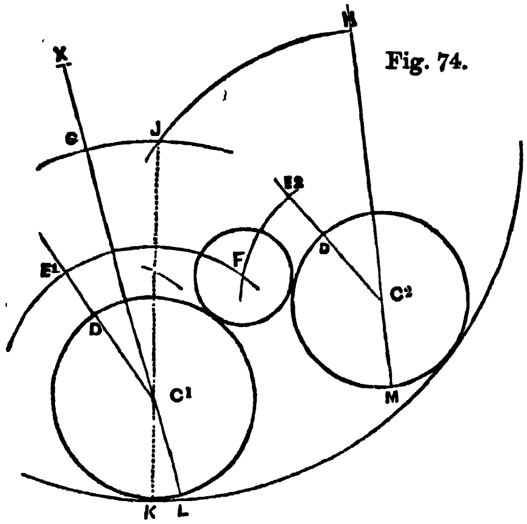

Fig. 74.

Any number of circles may be thus described.

To draw a circle of a given radius, to touch two given circles, C^1 and C^2 (Fig. 74).

Draw any radius in each circle, C^1 D and C^2 D, and produce them.

On these radii, beyond the circles, add to each the radius of the required circle—viz., D E^1 and D E^2.

From C^1 with radius C^1 E^1, and from C^2 with radius C^2 E^2, describe arcs cutting each other in F.

From F, with radius E D, describe the required circle, which will touch both circles.

If the required circle is to include both circles, draw any radius in each, as C^1 L, C^2 M.

Produce both these radii.

On the radius C^1, set off from L the radius of the required circle—viz., to K. Diminish this by the radius of circle 2—viz., to G.

On radius M C^2 set off L G—viz., M H.

From centres C^1 and C^2, with radius C^1 G and C^2 H, describe arcs cutting each other in J.

From J draw a line through C^1 to K.

With radius J K, describe the enclosing circle, which will touch circles C^1 and C^2.

THE CONCHOID* (Fig. 75).

The conchoid is a curve which always approaches a straight line, but never reaches it, however far the curve and straight line may be produced.

The straight line A B is called the *asymptote*, C D the diameter, and P the pole.

The asymptote A B, pole P, and diameter C being given, draw C P at right angles to A B.

On each side of D set off any number of equal parts, 1, 2, 3, 4, 5, 6, 7.

From P draw lines passing through these points.

From 1, 2, 3, etc., with radius D C, describe arcs cutting these lines in *a*, *b*, *c*, *d*, etc., and through these intersections trace the curve. The curve above the asymptote is called the *superior* conchoid. By setting off the same lengths *under* the line the *inferior* conchoid is obtained.

The conchoid has been used in architecture in drawing the slightly curved line which forms the profile or side of columns, called the *entasis*.

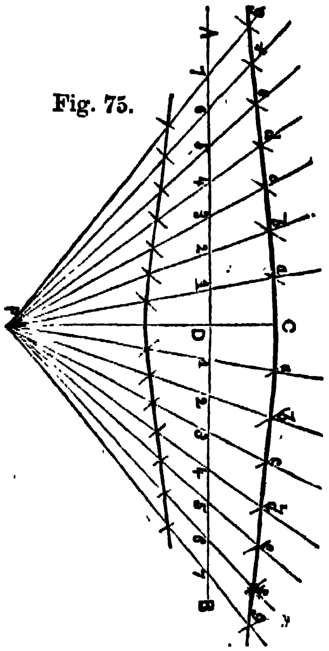

Fig. 75.

THE CISSOID.

This figure is sometimes called the cissoid of Diocles, from the name of its discoverer, who flourished about A.D. 150.

To draw the cissoid (Fig. 76).

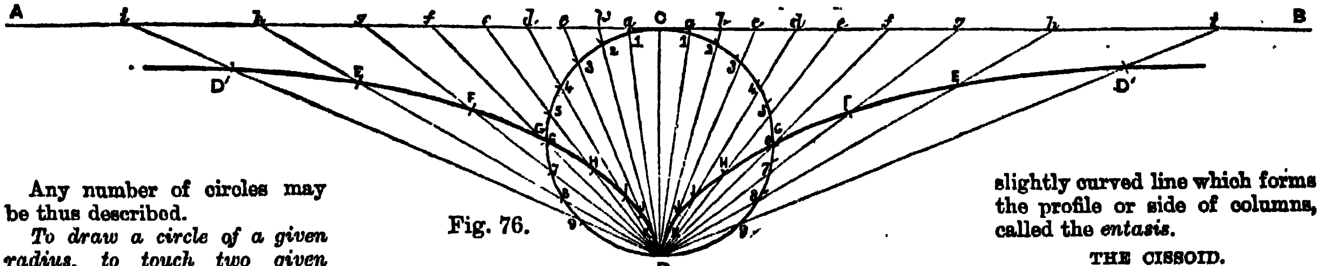

Fig. 76.

Draw any line, A B, and C D perpendicular to it. On C D describe a circle. From the extremity D of the diameter, draw any number of lines at any distance apart, passing through the circle, and meeting the line A B in *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, and *i*.

Take the length from *i* to 9, and set it off on the same line on each side from D—viz., to D′, D′.

Set off the length *h* 8 from D—viz., points E, E.

Set off the length *g* 7 from D—viz., points F, F.

Proceed thus with all the lines, and trace the double curve through D′ D′, E E, F F, G G, H H, I I, J J, K K, etc.

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* The conchoid was invented by Nicomedes about A.D. 450.

VEGETABLE COMMERCIAL PRODUCTS.

XIX.

VIII. PLANTS REMARKABLE FOR THEIR NARCOTIC AND POISONOUS PROPERTIES, YET USEFUL AS REMEDIAL AGENTS.

OPIUM (*Papaver somniferum*, L.; natural order, *Papaveraceæ*).—The poppy is an annual plant growing from two to four feet high, having flowers with two sepals and four white petals, with a violet spot at the base of each petal. Stamens numerous; pistil, a globular ovary or capsule, surmounted by a radiated stigma, containing partial dissepiments and numerous seeds.

The opium poppy is a native of Persia, and probably also of the south of Europe and Asia Minor. It is largely cultivated in those countries, and also in Egypt, Arabia, and British India, for the sake of its opium. Dr. Joseph Hooker thus describes this process:—"The capsules are sliced in February and March with a little instrument like a saw, made of three serrated plates tied together. From the incisions made by this instrument the opium oozes out as a milky juice, which as it dries becomes a soft brown sticky paste; each morning this paste is scraped off by means of small shells, and collected into jars, the contents of which are afterwards made into balls of about half a pound weight; these are often coated with the seeds of some species of *Rheum* or rhubarb plant. The balls are packed into chests, and exported to other countries."

Opium is produced in large quantities in India for consumption in China, on account of the great sale there, in spite of all prohibitions. Eastern nations generally are very fond of opium, which they smoke with their tobacco, or alone, and take in the form of pills. With us, it is much used in medicine as an anodyne, especially in the well-known preparation called laudanum.

In 1852 fifty-one tons of opium were imported into the United Kingdom, principally from the East Indies and Turkey. Turkey opium is considered to be the best, especially that which comes from Smyrna.

THE OPIUM POPPY (PAPAVER SOMNIFERUM).

TOBACCO (*Nicotiana Tabacum*, L.; natural order, *Solanaceæ*).—The tobacco plant is an annual, growing six feet high, having alternate, oblong, lanceolate, sessile leaves, and dingy red, funnel-shaped flowers. The leaves are viscid and pubescent, and are the parts used in the manufacture of the tobacco.

The tobacco plant is indigenous to the warm parts of America, and was unknown in the Old World before the discovery of that continent. It was first brought to the notice of the Spaniards in the year 1492, when Columbus and his companions saw the natives of Cuba smoking cigars. It was introduced into England in 1586 by Sir Francis Drake, from Virginia, where an English colony had remained for a year. The colonists are said to have brought tobacco with them on their return, and to have introduced into this country the practice of tobacco-smoking, or, as it was at first called, tobacco-*drinking* or *sucking*. Sir Walter Raleigh and other young men of fashion gave it every encouragement, by smoking themselves, and the habit was soon acquired by the English, as it had previously been by the Spaniards, the first method of imbibing the fumes being by means of a walnut-shell and a straw. The tobacco plant appears to thrive in all parts of the world in warm climates, and is now cultivated almost everywhere. The practice of smoking has become almost universal, both amongst savage and civilised nations; for no habit is more easily acquired or more difficult to relinquish than the use of this weed; hence its rapid progress amongst nations, in spite of all the efforts of their rulers at prohibition. The priests and sultans of Turkey and Persia declared smoking to be a sin against their holy religion; yet the Turks and Persians became the greatest smokers in the world. Pope Urban VIII. fulminated a bull against the use of tobacco, but the anathema fell to the ground. In Russia the smoker was threatened with the knout for the first offence, and with death for the second; yet the Russians are now constantly with pipes in their mouths. In our own country James I. wrote a book against it, called "A Counterblaste to Tobacco;" but instead of checking, it rather tended to promote the spread of the habit among his subjects.

Tobacco is manufactured in various forms to fit it for smoking, chewing, or snuffing, and the annual consumption in these different forms is so enormous that no estimate can be made of the quantity. In 1868 the imports into the United Kingdom amounted to 49,016,582 pounds of unmanufactured tobacco, and 3,051,398 pounds of manufactured tobacco, cigars, and snuffs; and some other nations are more addicted to the use of tobacco than ourselves.

After the plants have done blooming they are cut down and hung up to dry on poles; the leaves are then stripped from the stems, sorted, packed in boxes or casks, and shipped. On arriving in this country the leaves are taken out of the casks, and when their midribs have been removed, are spread on the floor and moistened with water. This is all that English manufacturers are allowed to do; on the Continent salt and sugar are added. The leaves are then compressed into dense cake and cut with a machine; and the cut tobacco, shaken out and afterwards steamed, is called, according to the leaf used, *Virginia shag*, *Maryland returns*, etc. In *Bird's-eye* tobacco the midrib is allowed to remain in the leaf, and forms those little white bits which have given it its fanciful name. The dried leaves, moistened with sugar and water, and pressed into cakes, form *Cavendish* and *Negrohead*, used for chewing and smoking. The same leaves moistened with sugar and water, beaten until soft, and then twisted into a sort of string, constitute *Pig-tail*. The leaves and stalks ground to powder and roasted form snuff, which is variously scented to suit the different olfactory tastes of customers. Cigars are only the dried leaves deprived of their midribs and wound into a sort of spindle form; cheroots are a variety of cigar, cut straight at each end, cylindrical, and tapering, broader at one end than the other; cigarettes are made by rolling up a small quantity of cut tobacco in a piece of paper (the leafy covering of the Indian corn is preferred), they are then smoked the same as cigars, but usually by moderate smokers.

There are numerous varieties of tobacco found in commerce. The principal sorts are—

North American tobacco, chiefly from the states of Virginia, Maryland, and Kentucky; but now, Tennessee, North Carolina, Louisiana, and Missouri also produce tobacco. Usually imported in hogsheads in the leaf, hence called leaf-tobacco.

South American tobacco, which is received in the form of cylindrical rolls two feet in length and one foot in diameter, made by rolling or twisting the tobacco leaves into a kind of rope about an inch or more in diameter, and then coiled up into these cylindrical rolls as the most compact and convenient form for transportation. We receive supplies from the Orinoco, Porto Rico, and from Maracaibo, and other South American ports. Roll tobacco is sent over in baskets made of twisted cane, called *canastras.* A considerable quantity of South American tobacco comes from the Brazils, both in the leaf and roll form.

The tobacco of Cuba is considered to be the finest in the world: Havana tobacco makes the best cigars.

Asiatic tobacco.—Asia produces good tobacco, but mostly for her own consumption. The European market, however, gets the Persian or Shiraz, which is much esteemed. Tobacco is also received from the Spanish island of Manilla in the shape of fine cigars, which are manufactured there, and then exported. A little tobacco is sent from India, Ceylon, Java, and Sumatra. From Turkey, Latakia tobacco is imported, which consists of not only the leaf, but also the flowers and buds of the plant; it is so called after the Turkish province of Latakia (the ancient *Antioch*), where it is grown. Some considerable trade is carried on in the south of Europe with this tobacco, which is excellent and mild.

TOBACCO BLOSSOM.

NUX VOMICA (*Strychnos nux vomica,* L.; natural order, *Loganiaceæ*).—A medium-sized tree, with opposite, ovate, stalked, three to five-nerved, smooth, shining leaves, and greenish-white flowers; a native of the East Indies, very common on the coast of Coromandel. The fruit is a globular berry, about the size of an orange, and with a smooth, hard, yellow rind, containing five seeds embedded in the pulp. These seeds are circular, flattened, rather less than an inch in diameter, slightly concave, silky in appearance, and fawn-coloured, or light drab in colour.

Strychnine, the most energetic poison known, is procured from the bruised seeds of the *nux vomica,* which are imported from Coromandel and Ceylon. It is sometimes employed in cases of paralysis, and is much used as a poison for rats and mice. The annual imports now average about 250 tons.

IX. MISCELLANEOUS MEDICINAL PRODUCTS.

ALOES (*Aloe Socotrina,* Tournef.; natural order, *Liliaceæ*).—This drug is the bitter, resinous, inspissated or thickened juice which is obtained from the leaves of various species of arborescent aloes growing in tropical climates. The species belong to the lily family, and have very large succulent leaves. The leaves are cut off close to the stem, and so placed that the juice is drained from them into tubs; this juice is then boiled until it acquires the consistence of honey, and poured into gourds or calabashes, when it hardens into a black compact substance, having an aromatic smell and an exceedingly bitter taste.

There are four principal varieties of aloes in commerce:—1. *Socotrine Aloes,* the best, produced by the above-named species, and so called from the island of Socotra, on the south coast of Arabia, in the Indian Ocean. 2. *Barbadoes Aloes*—of a very fine quality, produced by *Aloe vulgaris,* which is indigenous to the English island of Barbadoes, and also to Jamaica, Arabia, and the east coast of Africa. The Barbadoes aloes is imported from Barbadoes or Jamaica, usually in gourds weighing from sixty to seventy pounds, but sometimes in boxes holding about half a hundredweight. 3. *Cape Aloes*—very inferior, which is the product of *Aloe spicata;* raised in large quantities at the Cape of Good Hope, and brought over in chests and skins, the latter being preferred. 4. *Caballine* or *Horse Aloes.* This is the poorest kind; it is generally the refuse of the Barbadoes aloes, and, from its very rank and fetid smell, can only be used in veterinary medicine.

In 1863 we imported 312 tons of aloes, valued at about £25,685.

LIQUORICE (*Glycyrrhiza glabra,* L.; natural order, *Leguminosæ*).—This is a perennial plant, having long yellow fibrous roots running deeply into the ground, with an herbaceous stem four to five feet in height, and alternate pinnate leaves; flowers blue, papilionaceous, disposed in axillary spikes. Liquorice is a native of Italy, Spain, Sicily, and the southern parts of Europe; but it has been successfully cultivated in England, even from the reign of Queen Elizabeth, especially at Pontefract in Yorkshire, and Mitcham in Surrey. The greatest portion of our supplies of that extract of the root which forms the common liquorice of the shops, is obtained from the Spanish provinces of Arragon, Catalonia, and Valencia. The juice, procured from the root by compression in a mill, is boiled slowly until it becomes of the proper consistence, and is then made into sticks or bars from six to eight inches long, which are usually covered with bay leaves, and imported under the name of Spanish juice. Liquorice in the form of paste, or of the root itself, is in common use as an emollient in catarrh or cough; the root is also much used by brewers in the manufacture of porter. About 560 tons of the root and paste are annually imported.

IPECACUANHA (*Cephalis ipecacuanha,* Rich.; natural order, *Cinchonaceæ*).—This is a perennial plant growing in Brazil, about five or six inches high. The roots are several inches long, contorted, greyish brown, annulated, and about the thickness of a goose quill. The root of this plant affords a very important emetic medicine. It is imported from Rio Janeiro in bales, barrels, and bags.

RHUBARB (*Rheum palmatum;* natural order, *Polygonaceæ*).—The well-known purgative is the root of different species of *Rheum* growing in Tartary and other parts of Asia. There are two sorts—viz., Russian or Turkey rhubarb, which is brought by the Chinese to Kiachta, and there cleaned and sent on to Moscow and St. Petersburg; and the East Indian or Chinese rhubarb, which is shipped from Canton to Europe. There are several other varieties in the market, but the above are the most generally employed in this country. We import annually about 140 tons.

JALAP (*Exogonium parga;* natural order, *Convolvulaceæ*).—This valuable purgative medicine derives its name from Xalapa in Mexico, where it is very abundant. It is a handsome climbing convolvulaceous plant with delicate pink flowers and a tuberose root. The tubers, varying in size from a walnut to an orange, are dark umber-brown in colour, and much wrinkled. They are imported either whole or sliced; and we receive from Mexico about 150 tons per annum.

CAMOMILE (*Anthemis nobilis,* L.; natural order, *Compositæ*).—This is a well-known perennial plant, not unfrequent on dry, gravelly, or sandy heaths, and in the pastures of this country. The whole plant is intensely bitter, and an infusion of its flowers has long been esteemed as a tonic and stomachic, and used as an ingredient in fomentations. This plant is cultivated in England, and the flowers sold by druggists are the produce of the cultivated variety. Camomile flowers are also largely imported from France, Holland, and Germany.

SARSAPARILLA (*Smilax officinalis;* natural order, *Smilaceæ*).—The rhizome of this plant is cylindrical, and the roots (the sarsaparilla of commerce), abounding more or less in starch, are as much as ten feet long. It grows on the slopes of the mountains, and is confined to South America, where it ranges from 20° N. to 60° S. latitude. Jamaica, whence so much sarsaparilla is exported, does not produce any; the article known as Jamaica sarsaparilla is merely exported from the Spanish main for re-shipment. Sarsaparilla is imported in bales, and is known in the market as Lisbon or Brazilian, Honduras, and Jamaica or red sarsaparilla, of which the last is the most preferred. The imports in 1853 were 334,857 pounds.

Sarsaparilla is now regarded as a powerful alterative medicine in cases of physical debility. Its usefulness is daily manifested in the public hospitals, in cases of broken-down constitutions, so common to the class of patients by whom those establishments are frequented. It is chiefly used in rheumatic and cutaneous diseases. A concentrated liquid extract and a syrup are now prepared, which are the best forms under which it can be taken.

Senna (*Cassia lanceolata;* natural order, *Leguminosæ*).—The senna of the shops consists of the leaflets of different species of *Cassia*, such as the one above, and also *C. obovata*, *C. acutifolia*, *C. elongata*, and *C. Æthiopica* – all small shrubs with simple abruptly pinnate leaves, and yellow flowers, growing in tropical Asia and Africa. True senna leaves may be recognised by their oblique lower edges, and the inequality of their insertion into the footstalk; their odour is very faint, but peculiar; and their taste is sweetish and nauseous. The following varieties are met with in commerce:—

LEAF OF SARSAPARILLA.

1. *Alexandrian Senna*, or the leaves of *Cassia lanceolata* and *C. obovata*. These plants grow in Upper Egypt and Arabia. The harvest commences in September. The branches of the shrub are cut, collected into bundles, dried in the sun, and then threshed until the leaves are separated from them. This process breaks the branches, and the leaves thus become mixed with portions of twigs. The senna leaves so obtained are then put into sacks and conveyed to the Nile, and carried down the river to Cairo and Alexandria. There they are unpacked, sorted, and re-packed in large bales, and are then ready for the market.

2. *East Indian* or *Tinnivelly Senna*, the product of *Cassia elongata*, indigenous to Arabia and Africa, now cultivated in India, consists of long, thin, unbroken leaves of a yellowish-green colour. When good, it is fully equal to the Alexandrian

3. *Tripoli Senna*, the product of *Cassia Æthiopica;* not held in much estimation.

X. MISCELLANEOUS PLANTS OF COMMERCIAL VALUE.

Vegetable Ivory—Corozo Nuts (*Phytelephas macrocarpa;* natural order, *Phytelephanteæ*).—The *Phytelephas*, twenty feet in height, resembles a dwarf palm, with a majestic tuft of pinnate leaves; it is a native of the low valleys of South America between 9° N. and 8° S. latitude, and between 70° and 79° W. longitude. Its nuts are enclosed in a large capsule about the size of a man's head, and, owing to the procumbent habit of the stem, often rest on the ground. The albumen of the nut is "at first a clear insipid fluid, with which travellers allay their thirst; afterwards this same liquor becomes milky and sweet," consolidating by degrees till it becomes as white and hard as ivory. The nuts themselves, under the name of Corozo nuts, are imported in large quantities, being used by turners in making a vast variety of trinkets and articles to imitate ivory. About 80,000 of these nuts were imported in 1852.

Tonquin Bean (*Dipterir odorata;* natural order, *Leguminosæ*).—The seeds of the Tongo tree, a native of Guiana, are the well-known Tonquin beans used to scent snuff.

OBJECT DRAWING.—II.

In the last lesson we gave the plans of three blocks, placed in different positions in relation to the spectator. We now propose to show the method of drawing them.

Fig. 4.—First draw the square *a b e f*, representing the end of the object, which you will remember is vertical, and parallel to the edge of the table; and you must bear in mind also that you are to sit so that your chest is parallel with the table as well.

When you have decided as to the height of your eye in relation to the model, draw a horizontal line across your paper which shall have the same height in proportion to the square you have drawn as the real height of your eye has to the model; that is, supposing you see that your eye is three times the height of the model above its surface, then draw the horizontal line at three times the length of *a f* above *e f*. In the illustration a different height is taken, the purpose being to cause the student to *use his own judgment* instead of merely copying the drawing. The line H L is thus the horizontal line.

Now, on referring to the plan given in the last lesson, you will see, that supposing a sheet of glass (the surface on which we draw being supposed transparent) to stand on D E, then the line *b c* of the model (Fig. 3 [1]) would be at right angles to it; and it has already been shown that in drawing, all such lines should converge to the point of sight.

Therefore from *b* (Fig. 4) draw a line to P S, and as all the long edges of the model are parallel, the same rule would affect them equally; therefore draw lines from *e* and *f* to the point of sight.

Portions of these convergent lines will, as you can easily understand, form the edges of the solid, and you must terminate them by the perpendicular *g h* and the horizontal *h i*.

For reasons already mentioned, it is not intended to give in this place any rules for obtaining the distance of *g h* from *b e*. You must accustom yourself in object drawing to use your judgment, and you will, with but very little practice, be able to form a tolerably just idea of the distance; for you will see that if the lines had been drawn at either of the places indicated by dots, the object would, in the one case, appear merely as a flat piece of wood, whilst in others a balk of timber would be represented.

The plan (Fig. 3 [2]) of the next figure will show you that in this figure the length of the block is parallel to the picture-plane, the narrow edges receding. To begin this representation (Fig. 5), draw the rectangle *b e h g*, *b g* being double *b e*.

Now you will at once perceive that, as the block is immediately in front of you, you would not see either its left or right side, but only the top. On referring to the last view, you will be reminded that the ends *a b*, which in that case were parallel to the picture, are now at right angles to it. Therefore from *e* and *h* draw lines to the point of sight, then the line *f i* parallel to *e h* will complete the top, and the figure will thus show the front and top only.

Now proceed to sketch Fig. 6, which is the view of the block when standing on its end on your right side. Here, again, as the face is parallel to the picture, the front consists of the rectangle *b e h g*. Having completed this, draw lines from *e* and *h* to the point of sight. Then the perpendicular *f i* will complete the view, which will consist of front and side only; for as the end *h g* is higher than the horizontal line, you would not be able to see the top. Of course, you will understand that all the blocks need not necessarily be the same size—in fact, as you are placing your height at three times that of the square end, it will be necessary that this last one should be longer than the others; for as the length of the two already drawn is only twice their width, the end would still be below the horizontal line; but, as already stated, whatever may be the proportions of the objects, and whatever the height of the spectator, the principles here laid down will apply, and a very small amount of practice, guided by patient and intelligent observation, and urged on by the desire to learn, will soon enable you to judge whether your drawing truly represents the object as you see it.

Fig. 7 shows the mode of drawing a cube or other rectangular object when it is absolutely on a level with your eye, so that you do not see either the top or bottom of it; but as it is on your left hand you can see its right side. Of course, if it were placed immediately opposite to your eye—namely, in front of the point of sight, you would only see the front, but neither top, bottom, nor sides.

Fig. 8.—The object here represented is a plank, the *end* of which is parallel to the picture-plane, and the length at right angles to it—the whole object being placed *above* the level of the eye of the spectator (supported or suspended by means not shown in the drawing). It will be evident that, as the long edges of the plank are at right angles to the end, they will run directly from it into the distance, and must therefore be drawn to the point of sight, the lines forming the distant end being parallel to those seen in the front.

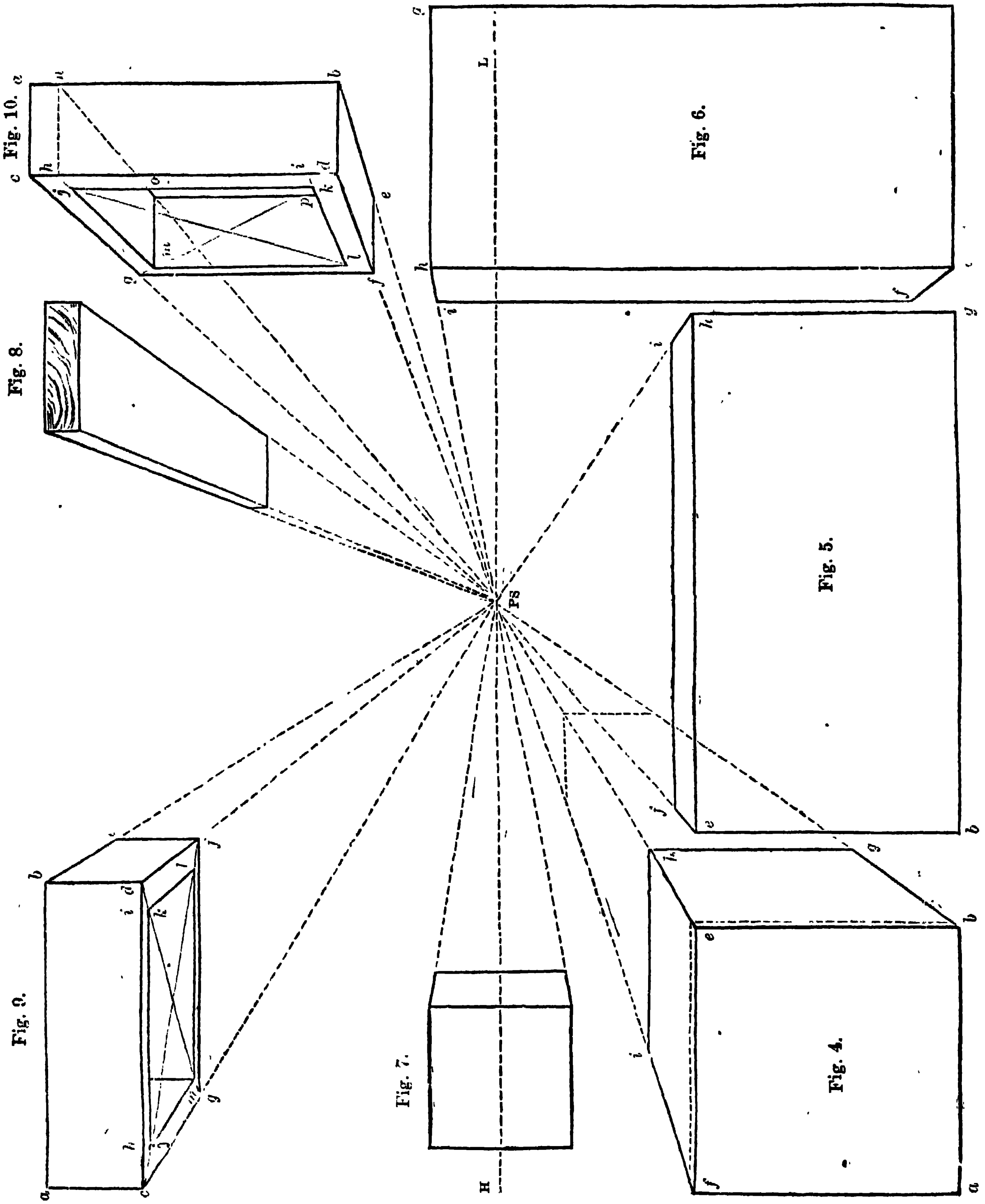


Fig. 9.—This object consists of four pieces of wood mitred together so as to form a piece of framing, or the sides of a shallow box.

Here, again, the side *a b c d* which is parallel to the front is to be drawn of its proper dimensions, and this being done, lines are to be drawn from each of the angles to the point of sight. The lines *c f* and *f g* will then complete the general view of the object as it would appear if it were a solid block.

It is necessary here to call your particular attention to this plan of drawing the *general* outline of the whole object before attempting the detail.

It must be evident that the entire of the interior lines, and all the detail, must depend upon the outline of the object *as a whole*, and therefore this system is impressed upon you.

The under surface of this slab, then, although in reality a *square*, will in your drawing be represented by the irregular four-sided figure $cdfg$.

Draw the diagonals cf and dg.

Now from c and d mark off on the line cd the distances ch and di, equal to the thickness of the pieces of wood of which the object is made, and from these points, h and i, draw lines to the point of sight.

The line drawn from h will cut the diagonals in j and m, and the line drawn from i will cut the diagonals in k and l.

Draw a line from j to k, and another from m to l; strengthen the lines jm and kl; then the figure $jklm$ will represent the inner square or inner edge of the wood of which the framing is formed.

The perpendicular at m represents the vertical junction of the inner sides of the framing. This completes the sketch, which may now be "lined in"—that is, nearly rubbed out, and the lines repeated in a clear and decided manner, remembering that in object drawing you ought not to use either rules or compasses.

Fig. 10 is a view of the same object when placed vertically and on your right-hand side.

The same lettering has been retained, and this will guide you in sketching the frame up to the stage shown in the last figure; but the present study is an advance on the previous one, for this is so placed that you can see through it; and it is therefore necessary to find the width of the distant side, which, although known to be the same as the near one, will of course appear diminished by its being removed from the front of the picture.

From h draw hn, which is of course the real width of the side, and from n draw a line to the point of sight.

Now from m draw a horizontal line which will cut this last line in o; then mo represents the length of hn when thus far removed from the plane of the picture.

Draw the perpendicular op; strengthen as much of no as is visible, and the sketch of the object will then be completed.

SEATS OF INDUSTRY.—X.

BELFAST.

BY WILLIAM WATT WEBSTER.

BELFAST, the capital of Ulster, the chief centre of commerce and industry in Ireland, and the metropolis of the linen trade and manufactures of the United Kingdom, is a town of comparatively modern origin, situated at the point where the river Lagan discharges its waters into Belfast Lough, or Carrickfergus Bay, about twelve miles from the Irish Sea, and a hundred miles from Dublin. The name Belfast is said to be a corruption of *Balu-fearsad—i.e.*, the town at the mouth of the river; but it need hardly be stated that this derivation is disputed, and that a variety of others have been suggested. The ground on which Belfast is built was reclaimed from the sea, and the greater portion of it does not stand more than six feet above the high-water mark. Owing to this cause it is occasionally visited by inundations and epidemics, but otherwise it is not by any means an unhealthy town, and in many respects it is most advantageously placed. Belfast Lough is a capacious bay, twelve miles in length and five miles broad at the entrance, affording safe anchorage for vessels of the largest size; while in the Pool of Garmoyle, four miles from Belfast, loaded ships float safely within a short distance of dry land. This estuary is protected from the westerly winds, which are the most frequent in that quarter, by a fine range of hills to the west, some of which are upwards of 1,000 feet high, and by the mountain of Divis to the north-west, which rises 1,567 feet above the level of the sea. The landward environment of Belfast is, indeed, exceedingly beautiful and picturesque. The northern shores of the bay are studded with elegant villas, and on an elevation to the south stands the aristocratic suburb of Malone, while the whole neighbourhood of the town is adorned with pleasing residences and pretty villages. From the flatness of the site the general aspect of Belfast, as seen from a distance, is not striking; but it contains many broad, straight, well-paved and well-lighted streets, and a large number of tasteful and expensive private mansions and public buildings. The mercantile quarter of the town lies on and near the quays that extend for about a mile below Queen's Bridge, which connects Belfast with the suburb of Ballymaccarrett, in the county of Down. The manufactories are chiefly situated on the rising grounds on the north and west sides of the town. Belfast can boast of a large number of excellent educational institutions and facilities, among which may be mentioned Queen's College, a picturesque pile of brick and stone in the Tudor style, opened in 1849; the Botanical Gardens, adjoining the College grounds; a Museum; the Royal Academical Institution, founded in 1810, which possesses a collegiate character, supporting professors in all branches of science, classics, and general literature; and the Belfast Academy, which at one time had a high classical reputation. The most celebrated public edifices are the White Linen Hall in Donegal Square, built in 1785, and the Commercial Buildings, an extensive block of houses at the south end of Donegal Street, erected in 1822, comprising a hotel, a news-room, an assembly-room (also used as an exchange), and various descriptions of offices.

Nothing is known regarding Belfast earlier than the twelfth century, at which date there appears to have existed a fortified station near the mouth of the Lagan. For a long period the town consisted of a few houses, a church, and a castle. Before the beginning of the fourteenth century, however, the place must have grown to considerable dimensions, and become of no small importance, for in 1316 the town and castle of Belfast were attacked and destroyed by Edward Bruce, and nearly two centuries elapsed before they came again into possession of the English. In the time of Henry VIII., Hugh MacNial Oge obtained a grant of the town and castle on certain conditions, which either he or his successors failing to fulfil, they reverted to the Crown. Randolphus Lane occupied the castle during the earlier part of the reign of Queen Elizabeth, but later on that sovereign appears to have conferred the castle and lands on Sir Thomas Smith, he undertaking to maintain a troop of horse and a company of foot for her Majesty's use, and to answer the royal summons when called upon. About the year 1604 Smith violated the conditions of the grant, and the reigning sovereign, James I., bestowed the castle and lands on Sir Arthur Chichester, the Lord Deputy, whose descendants continue to enjoy the lordship. Belfast increased rapidly after this transfer, and in the fifth year of the same king it obtained a charter of incorporation, which was renewed by James II., erecting it into a municipal and parliamentary borough, with the franchise vested in a sovereign or mayor, twelve burgesses, and a commonalty, and with the privilege of sending two members to the Irish Parliament. About this time many Scotch and English families were settled in the town and neighbourhood, in connection with the project of James I. for the formation of an English plantation in Ulster; and on the abolition of the port monopolies of Carrickfergus, in 1637, Belfast became the principal commercial depôt of the Plantation, and the seat of the Custom House. "At that era," says a writer in the "Encyclopædia Britannica," "commenced the first signs of the future progress of Belfast. The great influence exerted by this infusion of new blood into the district is attested at the present time by the persistency of the lowland Scotch dialect and accent, the prevalence of the Presbyterian religion, and the physical characteristics of the people, no less than by their commercial activity, industry, and enterprise." The progress of the town was suspended during the civil war, the inhabitants having first espoused the cause of the Parliament and afterwards that of the King. It was the expression of the feelings with which the Presbyterians of Belfast regarded the execution of Charles I., that drew upon the town the sarcasm of John Milton, who, it will be remembered, said, "Presbyter is but old Priest writ large." The secretary of Cromwell, in his "Observations upon the Articles of Peace with the Irish Rebels, etc.," dated 1649, described Belfast as "a small town in Ulster," "a barbarous nook in Ireland," and "a place better known by the name of a late barony than by the fame of these men's doctrines or ecclesiastical deeds, whose obscurity till now never came to our hearing." The zeal of the inhabitants of Belfast for the cause of civil and religious liberty led them to support the Prince of Orange against James II., and to proclaim him king, and their decisive action at this crisis was duly rewarded. William visited the town in June, 1690, shortly before the march to the Boyne, and so highly gratified was he with his reception, that he granted £1,200 per annum from the State coffers to the Presbyterian Synod of Ulster. This grant, afterwards increased and called the *Regium Donum*, was ordered to cease in 1869. After the Act of Union the municipal government of Belfast was modified by the addition of police and life commissioners to the former corporation, and this constitution continued till the passing of the Municipal Reform Act in 1841, when the present corporation, consisting of a mayor, ten aldermen, and thirty town-councillors, was instituted. From the time of the Union till the Reform Bill of 1832, Belfast returned one member to the Imperial Parliament, but by that Act the borough obtained two representatives.

Belfast is mainly indebted to the cultivation of linen manufacture for its importance and prosperity, and it has justly been styled the modern Panopolis, that, according to Strabo, having been the name of the principal centre of the linen manufacture of the ancients. Flax was grown and exported from Ireland, its fibre was spun and manufactured into cloth, and its seed crushed for oil in very early times. The old Irish or Celtic name for flax was *lhin*, and the term *poll a lhin*, still applied to certain places in the country districts, proves that the steeping of flax in pools was practised in Ireland at a very remote period. It is even considered probable that linen may have been introduced into Ireland by the Phœnicians. From the fragments of the Brehon laws which are still extant, it appears that the ancient rulers of the Irish tribes, who promulgated their decrees in the open air on the hill-tops, admonished the Brughaids, or farmers, to learn the art of cultivating and manipulating flax. In his "Annals of Commerce" Macpherson says, "We learn from Cronicles that about A.D. 500 fine linen was possessed by the inhabitants of Britain and Ireland. The bodies of the dead, at least of those of rank, were wrapped in it." But it is doubtful whether linen was extensively or generally manufactured in Ireland before its conquest by England in 1170; for in the list of exports given by Giraldus Cambrensis no linen manufactures are mentioned. Ireland had, however, an export trade in linen goods in the thirteenth century; for it can be proved that Irish linen was used at Winchester about 1272, during the reign of Henry III. In the middle of the fifteenth century reference is also found to linen imported into England from Ireland; and Leland states, with respect to Liverpool, about the year 1545: "Yrisch merchants cum moch thither, and moch Yrisch yarn that Manchester men do by there." Upwards of a century later, or about 1670, according to Macpherson, linen manufacture "began among the Scots in the north of Ireland, where it has to this day flourished more than in any other part. The vast quantities of linen which England takes of the Irish, enables them to pay for almost every kind of product and manufacture which we supply them with. Before they made much linen cloth, the people of the north of Ireland sent their linen yarn to England."

It was for a long period the favourite policy of English statesmen to settle foreigners in Ireland, and to establish new trades and manufactures. Sir Henry Sidney, the wise Lord-Deputy of Ireland in the reign of Queen Elizabeth, and the father of Sir Philip Sidney, in a letter to Sir Francis Walsingham, says: "I caused to plant and inhabit about forty families of the reformed churches of the Low Countries, flying thence for religion's sake, in one ruinous town called Swords; and truly, sir, it would have done any man good to have seen how diligently they wrought; how they re-edified the quite spoiled old castle of the same town, and repaired almost all the same; and how goodly and cleanly they and their wives and children lived. They made diapers and ticks for beds, etc." The Earl of Strafford, when Chief Deputy in the reign of Charles I., vigorously and successfully followed up this policy, bringing over flax-seed from Holland, and inviting French and Flemish artisans to settle in Ireland, and prosecute the cultivation of flax and the manufacture of linen cloth. Whatever may have been the motives that actuated the unfortunate statesman—and he certainly was not a disinterested benefactor of Ireland, for he tried to turn the improved industry into a personal monopoly—he deserves to be remembered for the impetus he gave to the linen manufactures of Ireland. The earl invested £30,000 of his private fortune in the enterprise, and it was afterwards made one of the grounds of his impeachment that "he had obstructed the industry of the country by introducing new and unknown processes into the manufacture of flax." The Duke of Ormond also distinguished himself by the encouragement he gave to foreigners possessed of skill in linen manufacture to settle in Ireland; and two years after the Restoration he pushed a bill through the Irish Parliament, entitled "An Act for Encouraging Protestant Strangers and Others to inhabit Ireland," which duly received the royal assent. In his "Miscellanies," first published in 1681, Sir William Temple says, "No women are apter to spin linen thread well than the Irish, who labouring little in any kind with their hands, have their fingers more supple and soft than other women of the poor condition amongst us; and this may certainly be advanced and improved into a great manufacture of linen, so as to bear down the trade of France and Holland."

Notwithstanding all that had been done since the time of Elizabeth, however, the total annual value of the linen cloth exported from Ireland at the accession of William III. did not amount to £6,000. Before the passing of the Act of 1697, William invited Louis Crommelier, a Huguenot refugee then settled in Holland, to undertake the office of Royal Superintendent of Linen Manufactures in Ireland. Crommelier belonged to a family which had carried on linen manufacture in France, in all its branches, for upwards of four hundred years, and he himself had upwards of thirty years' experience. In 1698 he arrived in Ireland, accompanied by his son, and selected the ruined village of Lisnagarvey as the site of the new government manufacturing establishment A little colony of refugees, of all ranks and many trades, soon became planted at Lisburn, which is about seven miles from Belfast, and the place quickly began to wear a prosperous aspect. Many other colonies of French and Flemish artisans were established in the south of Ireland, where they carried on various branches of industry, but only those in the north were permanently successful, although Cork, Limerick, and Waterford enjoyed superior facilities for trade. Among the French settlers in the north of Ireland may be mentioned Peter Goyer, a Picardy manufacturer, who began the manufacture of silk and cambric at Lisburn.

At that time woollen goods were the staple manufacture of Ireland, and the prosperity of the trade soon roused the jealousy of English rivals. Protection was not an economic heresy in those days. The importation of yarn and linen and woollen goods from France was strictly prohibited, and at one time it was a penal offence to wear French cambric. These restrictions were, of course, believed to be beneficial to the people of England, and the same arguments which excluded French manufactures from the English markets were used to exclude Irish woollens. In 1698 the English House of Peers memorialised King William to use his influence to discourage the woollen manufactures of Ireland, and, by way of recompense, "to encourage the linen manufactures of the said kingdom, pursuant to an Act of Parliament in the year 1696." The English House of Commons also addressed the king, requesting him to induce the Irish "to cultivate the joint interest of both kingdoms; and that as Ireland is dependent on and protected by England in the enjoyment of all they have, they would be content to apply themselves to the linen manufacture, whereby they would enrich themselves and be beneficial to England at the same time." The king replied, "I shall do all that in me lies to discourage the woollen manufacture in Ireland, and to encourage the linen manufacture, and to promote the trade of England;" and the Irish Legislature immediately imposed heavy duties upon the export of all woollen cloths. As a matter of course, the woollen manufacturers were completely ruined; thousands of families were forced to emigrate, their labour and skill being no longer required; and in the south and west whole districts were nearly depopulated. In 1699 an Act was passed for the special encouragement of the Irish linen trade, and a board called "The Trustees for the Linen and Hempen Manufactures" was established at Dublin, for the purpose of fostering the growth of linen manufacture in the north of Ireland. At first an annual sum of £6,000 was placed at the board's disposal; but afterwards its revenue was increased to £20,000, and at this sum it remained for a long period. The money was spent in premiums for the growth and importation of flax-seed for the cultivation and preparation of the largest quantities of flax-fibre, for the invention and distribution of new and improved implements, for the erection of scutch-mills, and for the production of the best qualities of yarn and cloth. A number of officials were appointed in the localities where the manufacture was carried on, and inducements were held out to the skilled weavers and flax-dressers of foreign countries to settle in Ireland. This board continued in existence till the year 1828, when it was finally abolished.

In his "Dictionary of Commerce," Mr. McCulloch makes the following criticism on the mistaken policy which successive governments so long pursued, in reference to the Irish linen trade. "For a long period," says this able economist, "previous to 1830, bounties were granted on the exportation of linen. In 1829, for instance, notwithstanding it had been greatly reduced, the bounty amounted to £300,000, or to nearly *one-seventh* part of the entire real or declared value of the linen exported that year. It is not easy to imagine a greater abuse. A bounty of this sort, instead of encouraging the manufacture, rendered those engaged in it comparatively indifferent to improvements; and though it had been otherwise, what is to be thought of the policy of persisting for more than a century in supplying the foreigner with linens for less than they cost? We have not the least doubt that were the various sums expended in well-meant but useless attempts to force this manufacture, added together with their accumulations at simple interest, they would be found sufficient to yield an annual revenue little, if at all, inferior to the entire value of the linens we now send abroad. And after all, the business never began to do any real good, or to take firm root, till the manufacture ceased to be a domestic one, and was carried on principally in mills, and by the aid of machinery—a change which the old forcing system tended to counteract. The only real and effective legislative encouragement the manufacturer ever met with, has been the reduction and repeal of the duties on flax and hemp, and the relinquishing of the absurd attempts to force their growth at home." But it is to be feared that the discouragement of the woollen trade, and the encouragement of the linen manufactures, were intended to serve another object than the obvious one. The woollen trade was principally carried on by the Roman Catholics in the west and south of Ireland, while Protestant Ulster was the chief seat of the linen manufacture; and by favouring the latter, and destroying the former industry, the Government of King William probably thought it was propagating Protestantism and checking Popery.

Previous to the introduction of machinery, Belfast was but a small town; its population in 1760 being less than 9,000. Cotton-spinning machinery was first used in the town in 1777, and machinery for the spinning of flax in 1806; and about the year 1792 shipbuilding was added to its industries. The progress Belfast made after the first-mentioned of these dates was rapid and steady. In 1798 the population numbered 18,320; in 1831, 48,224; in 1841, 75,308; in 1851, 100,300; and in 1861 it was returned at 119,718, of whom 40 000 were Roman Catholics.

It was not till 1824 that the idea of erecting a spinning-mill on an extensive scale was entertained by a body of the Belfast linen manufacturers, and the project was not carried into execution till 1828. In that year the Messrs. Mulholland built their works, which are in active operation at the present day, and since then an extraordinary extension of machinery has taken place. The linen exported from Belfast in 1835 amounted to 53,881,000 yards, and was valued at £2,694,000, and in 1863 the *Linen Circular* calculated the aggregate value of the linen manufactured in Belfast and its suburbs during that year at £10,000,000. In 1864 the total imports into Belfast amounted to upwards of £10,000,000, and the exports were stated at a total of £8,000,000. There were in the town and neighbourhood of Belfast in the year 1858 thirty-three steam spinning-mills, or about one-half of all the steam spinning-mills then in Ireland, which numbered seventy-six. In Ure's "Philosophy of Manufactures" (1861) it is stated, that "of the Irish flax factories thirty-nine, or nearly one-half, are situated in Belfast and its environs, and outside the province of Ulster there are but nine." Mr. A. J. Warden, the author of the "History of the Linen Trade," has remarked that there is a decided tendency to centralise the linen trade in Belfast. "Many of the eminent houses," he says, "have opened sale-rooms in Belfast, at the same time conducting their operations as formerly in the localities where their manufactories and bleach-fields are." During the past four years the linen trade in the north of Ireland has been rather depressed, and last year it was injuriously affected by the outbreak of the war between France and Germany. In the autumn, however, the exports to the United States were very large, and nearly, if not quite, compensated the loss of custom from Germany and France.

The commerce of Belfast is very extensive and rapidly increasing. Only a comparatively small part of the exports are sent direct to foreign countries, and the most important branch of traffic is across the Irish Channel to Great Britain, and principally to Liverpool. About forty steamers are regularly engaged plying between Belfast and the principal ports of England and Scotland, besides Dublin and Derry, and the chief articles of export are linen and cotton manufactures, linen yarn, corn, meal, flour, provisions (including under that term hams and bacon), tow, and horses. The increase that has taken place in the shipping of the port is, indeed, quite as remarkable as the growth of the manufactures. In 1700 there were only five small vessels owned in Belfast, while in 1865 there were 326 sailing vessels over 50 tons burden, and 153 below 50 tons, besides 11 steam-ships belonging to the port; and considerably over 8,000 vessels, with an aggregate of about 1,250,000 tons burden, are now annually entered and cleared at the port. The inland trade of the town is carried on by means of the Lagan, a canal, and three railways.

There are five extensive cotton-mills in Belfast, in which velvets, fustians, jeans, ticking, ginghams, calico, muslins, etc., are made. Besides the industries already noted, calico-printing, bleaching, and dyeing are carried out on a large scale in Belfast, and it also contains important iron foundries, machine shops, chemical works, glass works, distilleries, breweries, flour-mills, tanneries, roperies, etc.

The climate and soil of Ireland are more favourable to the growth of flax than the climate and soil of either of the sister kingdoms, and a society has long been established at Belfast for promoting its cultivation. This society has not been uninfluential, but it is considered doubtful whether its exertions have been beneficial to the country. In 1847 there were only 58,312 acres of land under flax in Ireland, while the average acreage during the three years 1865, 1866, 1867 was returned at 256,015. Nearly the whole of the flax grown in Ireland finds its way to Belfast. The condition of the working classes in Belfast will compare favourably with that of the artisans of any other town in the kingdom, and in some respects they are better off, for they seldom suffer from temporary interruptions of trade; while the landed aristocracy are in a small minority, and the middle classes enjoy all the comforts and many of the luxuries of life.

TECHNICAL DRAWING.—XXXI.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*).

FIG. 284 is the crank-pin that is held by a cotter, or wedge, in the smaller end of the crank, and it receives the larger end of the connecting-rod (Fig. 285), which end consists of a solid square-shaped block, through which passes a gib and cotter. The brass bearings, or "brasses," are held in position by a strap which passes over them, and are kept from opening by the gib, and tightened by the cotter: a small set-screw, with hexagonal head, holds the cotter in position when driven into its place.

The smaller end of this connecting-rod (Fig. 286) is made differently, for it passes inside the closed jaws of the motion-block (Fig. 312), and the brasses need no flanges to prevent their coming out of place. This end is made solid without any strap, and the brasses are tightened up by a cotter and screw, no gib being required. Other forms of connecting-rods are in common use, the kind generally adopted for marine engines being shown in Fig. 219 (Vol. I., page 325).

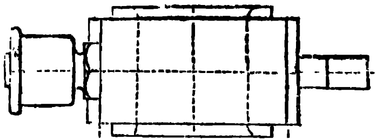
Figs. 287 and 288 are end elevations of the connecting-rod, and Fig. 289 a section across the middle to show its thickness.

Figs. 290 and 291 are views of the eccentric-rod, which is merely a smaller and lighter connecting-rod between the eccentric and slide-valve. Both connecting-rod and eccentric-rod should be as long as possible, because if too short they cause an irregular distribution of steam in the cylinder, and injurious pressure upon the slide-bars.

Figs. 292 and 293 are views of the valve-rod, which enters through a gland in the valve-box cover, and holds the slide-valve, its outer end being in connection with the eccentric-rod, and thus the movements of the eccentric are communicated to the slide-valve. The screw upon this valve-rod is provided with double sets of nuts, the outer, or second one, being called a lock-nut, and its office is to hold the inner ones in any desired position. When adjusted into its place, the outer nuts are screwed fast upon those inside, preventing them from becoming loosened easily. Wherever there is much vibration, single nuts are liable to loosen, and lock-nuts form a simple, cheap, and most effective method of preventing this evil. The centre portion of the screwed end is turned smaller, so that the inner nuts may slip over it, and thus be more expeditiously inserted than if they had to be screwed along the whole length.

Fig. 294 is the piston-rod, partly shown with the piston in Fig. 275. This rod is made of steel, for it has to endure much friction, and would wear away if made of iron. One end is screwed into the piston, and the other conical end fits into a corresponding hole in the motion-block (Fig. 312), and is fastened by a cotter into its position there.

Fig. 295 shows the motion-block pin, which forms a bearing for the smaller end of the connecting-rod (Fig. 286), and is inserted through a corresponding hole in the motion-block (Fig. 312). A small piece of wire is inserted close under the head of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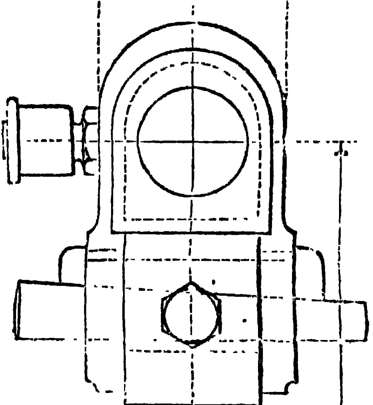
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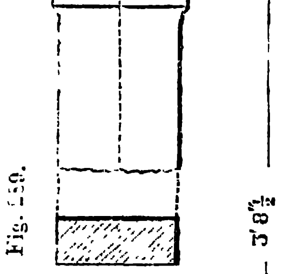
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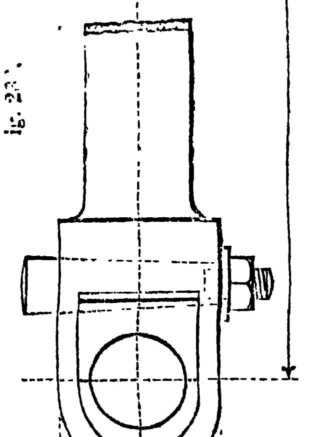
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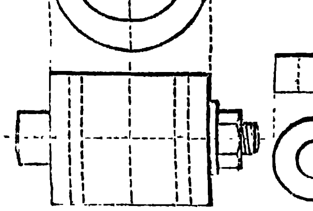
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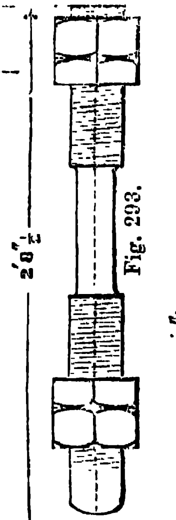
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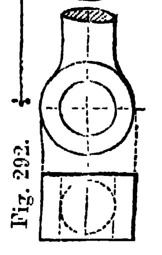
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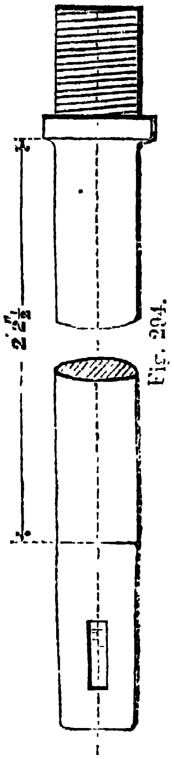
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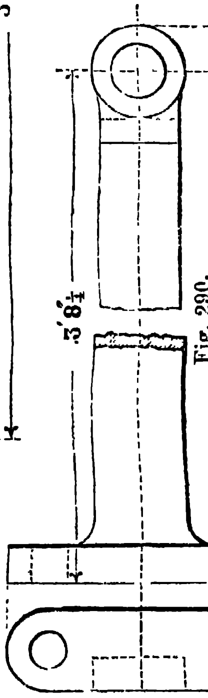
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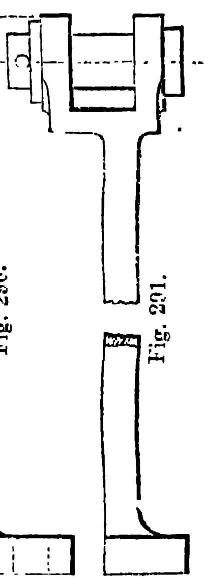
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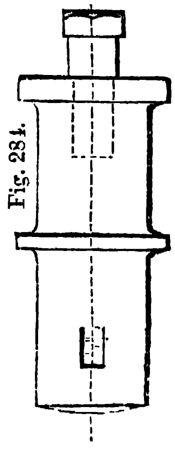
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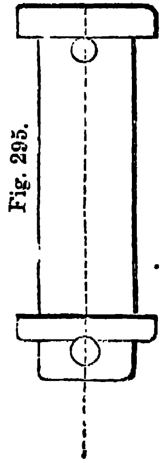
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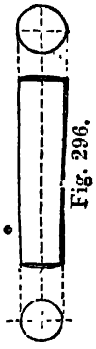
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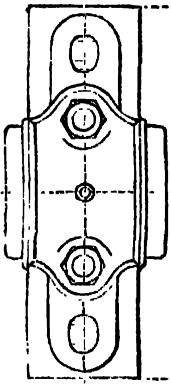
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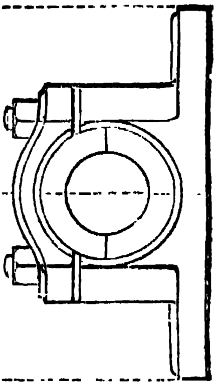
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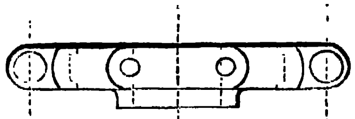
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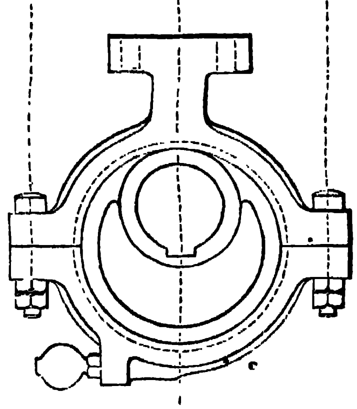
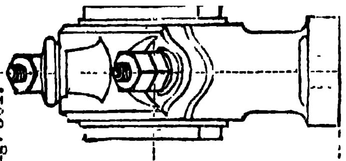


Fig. 299.

this pin, and fitting into a keyway in the motion-block, prevents the pin from turning round, and compels the brasses of the connecting-rod to move upon it.

As any pressure on the piston causes a side strain to the cylinder, pedestals, etc., which the bolts alone are unfitted to withstand, the steady-pin (Fig. 296) is a very simple, cheap form of key to hold all the parts in their proper position in spite of side strains. Holes are drilled through the cylinder and pedestal flanges, and these conical pins are driven in and form a most effective key, which is easily removed when necessary for taking the engine to pieces.

Figs. 297 and 298 are a plan and elevation of the plummer-block or pedestal, which carries the hinder end of shaft near the fly-wheel.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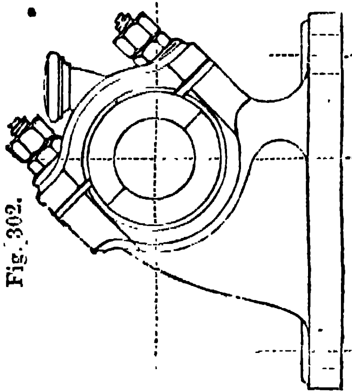
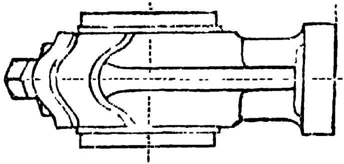


Fig. 302.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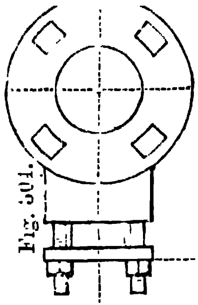
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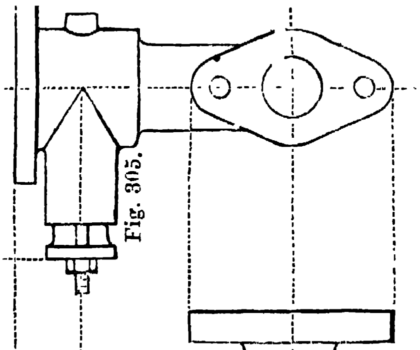
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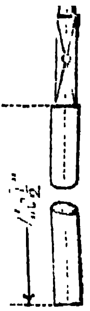
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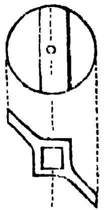
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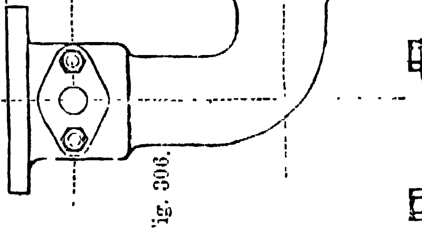
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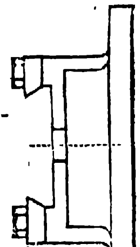


Fig. 316.

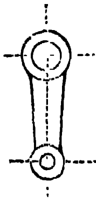


Fig. 308.

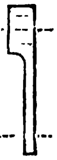


Fig. 309.

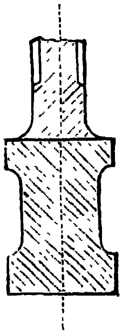


Fig. 311.

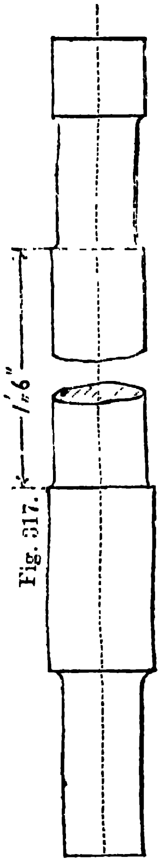


Fig. 317.

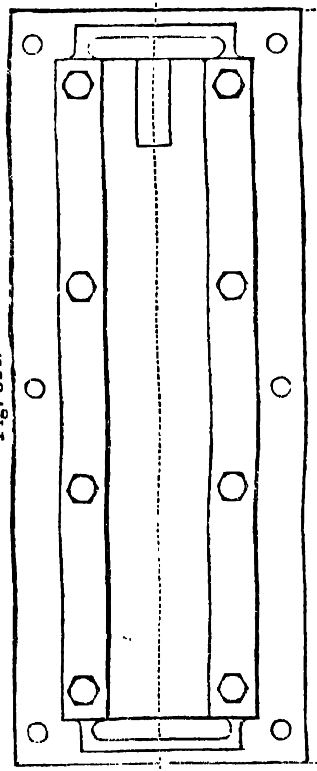


Fig. 314.

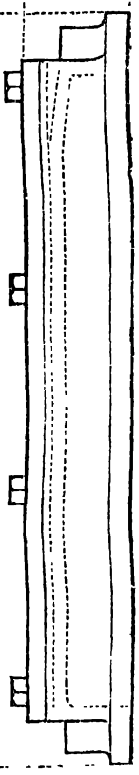


Fig. 315.

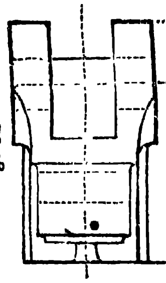


Fig. 312.

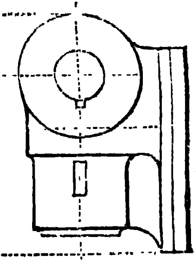


Fig. 313.

Fig. 299 and 300 are two views of the eccentric which moves the slide-valve, as already stated in the preceding lesson. An eccentric is nothing more than a disguised form of crank, where what corresponds to the pin is sufficiently large to embrace the shaft. Its movements are the same as those of a crank, and it forms an excellent method of moving the valves of steam-engines. The central portion is keyed on the main shaft, and the two rings placed around it are held in position by bolts with locked nuts. A small oil-cup behind serves to keep the working surfaces lubricated.

Figs. 301, 302, and 303 are front, side, and back views of the oblique pedestal behind the crank. As the pressure of the piston is altogether from the side, such a pedestal as Fig. 298 would wear away at the joints of the brasses without the means of tightening, and therefore in this case would be unsuitable; but the side pedestal shown is properly arranged for resisting the pressure communicated to the crank, and being tightened up as it wears.

Figs. 304, 305, and 306 represent the throttle-valve pipe in three views; Fig. 307 the valve itself; and Figs. 308, 309, and 310 its lever and shaft. This contrivance is really an imperfect form of valve or tap, which, closing, reduces the quantity of steam admitted to the cylinder. It is worked by the governor, in the manner shown in Figs. 338, 339.

Fig. 311 is a section of the fly-wheel rim and one of its arms; side elevations being shown in Figs. 338 and 339.

Figs. 312 and 313, the motion-block, which forms a connection between the piston-rod and connecting-rod; and also works in the slide-bar (Figs. 314, 315, and 316). An inspection of the general drawing will show that the angular direction of the connecting-rod would strain the piston-rod, unless means were adopted for resisting it. The motion-block slides upon a smooth surface parallel with the axis of the cylinder, and receives the angular thrust of the connecting-rod, so preventing any undue strain coming upon the piston-rod. There are many different forms of slide-bar in use, but the one shown is as neat in appearance as any, though it has a disadvantage in offering a larger surface for pressure below than above, for the engine to run round to the right—that is, in the direction that the hands of a watch turn—and then the pressure on the motion-block is always downwards.

The fly-wheel shaft (Fig. 317) is shown as if partly broken, the object being to represent its special form to as large a scale as possible, without occupying inconvenient space on the page by mere length. It will be observed that the corners are rounded instead of being made square. This is a most important feature in shafting exposed to any strain, for when the angles are made square, shafts will sometimes break, although amply strong enough in appearance for the work to be borne.

CHEMISTRY APPLIED TO THE ARTS.—IX.

BY GEORGE GLADSTONE, F.C.S.

CANDLE-MAKING.

WONDERFUL progress has been made during the last few years in the art of making candles; those which are now in common use in the best circles being of a composition wholly unknown to the last generation. The article used almost universally by the lower orders remains, however, much the same as it then was. For certain purposes the old-fashioned dips are not superseded. In the first place they are cheap, and in the second they are not liable to gutter, which renders them most appropriate when a candle is to be carried about: the readiness with which some of the superior sorts of candles shed the melted portion while being carried about a house is often a source of great annoyance, and cause of damage to the carpets and other articles of furniture. The necessity of snuffing the dips is, however, an objection, as they give only a very indifferent light in the interval, and if not attended to, the burnt portion of the wick is apt to fall and cause waste.

Tallow candles belong to two categories—*dips* and *moulds*. The latter are superior to the former, both in composition and appearance, though actually made of the same materials. The tallow used for such purposes often contains a mixture of various fats, such as those of beef and mutton, hog's lard, etc. Such ingredients are liable to turn musty and rancid, on which account it is necessary to purify them, first by melting them and straining off all the membranous substances which may be mingled with them, and subsequently boiling the fat up with a little water and sulphuric acid. If mould candles are to be made, the tallow is generally subjected to other processes in order to increase the firmness, and at the same time to improve the colour. Pressure is sometimes used to separate the more liquid portion; but alum, borax, and other substances are also often mixed with the fat in order to clarify and harden it.

The wick of a tallow candle needs to be rather bulky and loose in texture, so as to allow the melted tallow to rise freely: cotton, loosely twisted, fulfils these conditions best. A wick which will not require snuffing can be made by plaiting the thread tightly, because in such case the wick will never keep straight as it burns, but will curl up until the end projects to the outer edge of the flame, where the heat is sufficiently intense to burn away the carbon altogether. Such wicks, however, will not absorb sufficient tallow to produce a satisfactory light, and are therefore reserved for the better descriptions of candles, which burn with a much brighter flame. For large candles two wicks are sometimes used, and they are so placed that they bend in opposite directions as they burn, and thus produce a broader illuminating surface.

To make *dips*, the wicks are attached to a frame, and immersed in a trough of molten fat, from which they are gradually withdrawn, to allow the adherent tallow to cool. This dipping is repeated from time to time until the candles have acquired the proper thickness, the subsequent dippings after the first being more rapidly performed, and in tallow of a rather lower temperature.

Mould candles suggest by their name the plan adopted in their manufacture. The mould consists of a metallic tube of the proper shape and size, through which the wick is passed, and then the molten tallow is poured in and left to cool. A large number of these moulds are arranged in one frame, so that they are all filled at one operation. Pewter is found to be the best material of which to make the moulds, as it is not affected by any acid there may be in the tallow. They should not be made any thicker than is necessary for the sake of durability, as the thinner they are the more rapidly will the cooling take place.

Sperm candles are much superior to the moulds, and until within a comparatively recent period were the only rival of the real wax candle. The name is simply a contraction for spermaceti, the article from which they are principally made. It is a kind of fat which is obtained from the head of a particular species of whale, *Physeter macrocephalus*, which, when the oily portion is expressed, forms a solid of pearly whiteness and of crystalline structure. It does not contain any glycerine, and hence it is not greasy to the touch. For this reason, as well as their beautiful appearance and high illuminating power, sperm candles have justly enjoyed a high reputation. In order to free the spermaceti thoroughly from the oily portion, pressure is not found sufficient, even though hydraulic presses of great power are used. After it comes out of the press, therefore, it is frequently boiled along with a little caustic soda in solution, just sufficient to combine with the residual oil, which will then be converted into a soap and can be skimmed off the surface. If too much alkali were added the spermaceti would in like manner be saponified, and a loss of material would ensue. It is afterwards washed with water, which removes all the soap that may have remained over from the skimming. The material being thus prepared, the candles are made in moulds with plaited wicks as above described.

The improvements in candle manufacture which have taken place of late years have caused the real sperm and wax candles to be greatly superseded. Every one is now familiar with those made of stearine or stearic acid This substance is present not only in animal fats, but also in many of the vegetable oils; palm and cocoa-nut oils contain large quantities, and are now very extensively used in the preparation of stearine. The other principal ingredients are margaric and oleic acids, and glycerine. The former of these need not be altogether removed, but the oleic acid is much too liquid to suit the candle-maker, and the glycerine must be extracted, because it will not burn, and its presence would therefore diminish the illuminating power. Stearine, when thoroughly separated from these several substances, is a firm crystalline body, and makes a hard, clean, and good-looking candle, which gives a strong bright light.

Palm oil, when in its natural state, is very highly coloured, and it has therefore to be bleached. Most of the other substances are more or less tinged, and it is desirable to submit them also to a similar process. This is usually done after the ingredients which are not required have been removed from the crude oil.

There are several distinct processes for the separation of the stearic acid. Superheated steam will serve the purpose, and partially bleach it at the same time. The fatty matter is placed together with water in an iron chamber capable of bearing a pressure of about 2,000 pounds to the square inch, and is raised to a temperature of from 500° to 600° Fahrenheit. The glycerine then combines with the water, and on the contents being drawn off into a tank, the stearic acid separates from the other substances.

The sulphuric acid process is, however, more commonly adopted, especially in the conversion of palm oil. It is first melted in large vats, and then passed into a leaden tank, where it is heated by steam to about 350° Fahrenheit. Strong sulphuric acid is then gradually added to the extent of about $\frac{1}{10}$ of the weight of the oil, the boiling being kept up all the time. After being left awhile to settle, the oil is transferred to the stills, where it is distilled over at a high temperature, the glycerine coming off first, and the ultimate product forming a tolerably firm substance on cooling, which without further preparation may be converted into candles. Those so made are called *composites:* the quality, however, can still be considerably improved. In order to make the best stearine candles, the fatty acid is shredded by a machine, and then spread evenly upon mats, which are piled one upon another, and then put under a hydraulic press: all the oleic acid is thus expelled. On taking the stearine out of the press, it is again melted with a weak aqueous solution of sulphuric acid, and after the liquor is drawn off, a very pure and hard stearine results on cooling.

A third plan of separating the glycerine is by converting the oil into a soap. For this purpose the alkalies used by soap-boilers are too expensive; caustic lime (hydrate of calcium), which is found to answer equally well, being used instead. The oil having been melted in vats by the introduction of steam, slaked lime, worked up with a sufficiency of water to make it about the consistency of cream, is gradually added, until the proportion of lime to the oil is about 15 per cent. by weight, the mixture being well stirred all the time. The vats are then shut down and kept at a high temperature for some hours, during which period the lime has combined with the fatty acid, forming a soap, while the glycerine has combined with the water. The mixture is then allowed to cool, the glycerine and water drawn off, and the residue well washed with cold water. The lime-soap contains oleic as well as stearic acid, but the next step is to separate the lime and leave the acids perfectly free. Sulphuric acid, having a great affinity for lime, is employed to effect this object. The soap is heated to something under the boiling-point with sulphuric acid and water, the weight of concentrated acid employed being about one-fourth of that of the soap to be decomposed. When the fat has separated and risen to the surface of the liquid, the sulphate of lime and water is drawn off, and the fatty acids are left to cool and solidify. The oleic acid is then usually removed by pressure, and the stearine is ready to be made into candles.

At first some difficulty was experienced in making them in moulds, on account of the great tendency of the stearine to crystallise. It was found that a small admixture of arsenic would prevent this, but its poisonous reputation prohibited its use. An addition of a little wax has the double advantage of preventing the crystallisation of the stearine, and of increasing the beauty of the candles; but a still simpler expedient has since been hit upon, all that is necessary being to regulate the temperature when the moulds are filled, so that the stearine shall only be just hot enough to allow it to run.

Within the last twenty years or so, a very important addition has been made to the sources of supply of the ingredient most important to the candle-maker. About that time many attempts were made to convert the peat bogs of Ireland into candles, but they were generally looked upon with incredulity. As a scientific experiment the attempt was quite legitimate, but as a commercial operation the candles produced were found to be vastly too dear. The material distilled from the peat was paraffin, but it could only be obtained in very small quantities and at great expense. The earth-oil from Rangoon, which is obtained in wells, was found to be rich in this ingredient, and it could be separated from it at a sufficiently cheap rate. It was also found to be present in considerable quantities in the Cannel coals, and the oil shales associated with them, and could be separated by distillation at a low red heat. The Bathgate shales near Edinburgh (otherwise called Boghead coal or Torbanehill mineral) being very rich in hydro-carbons, large works have been carried on there since the first discovery of their value, for the distillation of the paraffin and the mineral illuminating oils. It is now produced wherever cannel is found, the principal centre of the trade in England and Wales being in Flintshire, Cheshire, and Lancashire, coal of this description being raised at Mold and Wigan. The petroleums of the United States also yield this substance.

Paraffin is a pure hydro-carbon, containing nothing else than carbon and hydrogen, being precisely the same ingredients as in ordinary coal-gas, though in another form, gas being produced by distillation of the same substances at a much higher temperature. It is a colourless solid, not at all greasy to the touch, which melts readily at a low heat, and burns with a brilliant flame. Unlike the oils and fats spoken of above, it does not contain any glycerine. Ozokerit is also a mineral hydro-carbon, distilled from an oil shale obtained in Southern Russia; it has, however, a higher melting-point, which is an advantage in some respects. Pure paraffin melts at about 120° Fahrenheit, which is too low a point to be safe in a hot climate, and on which account it is generally mixed with stearine, the two together forming a very excellent candle.

There is one other article from which candles are frequently made, which demands consideration—wax. The material is not only different in character, but the manner of dealing with it is also quite distinct. Bees'-wax is a very familiar substance which scarcely needs description, but there is also Chinese wax, which is the exudation of an insect, and vegetable waxes, which are prepared from the berries and fruits of certain plants.

Bees'-wax is usually of a very decided yellow colour: it must in consequence be bleached. The ordinary bleaching agents cannot be applied, and therefore the wax has to pass through a process somewhat similar to what used to be adopted with textile fabrics in olden days. The wax is first melted by the agency of steam, to separate any extraneous matters, and then made into thin sheets, which are spread out in the open air and watered from time to time, until the greater portion of the colour is lost.

Wax candles are seldom made in moulds, on account of the difficulty of drawing them out after they have cooled. They are therefore usually made by another process, which is termed basting: the wicks are suspended to a frame over the caldron of melted wax, and instead of being dipped into the liquid, as in the case of tallow, the workman takes the wax up in a ladle, and pours it over the row of wicks in succession, until they have attained about one-third of their ultimate thickness. They are then removed from the frame, and rolled between marble slabs, in order to make them quite smooth and of uniform thickness. The candles are again suspended to the frame and basted as before, then rolled, and the ends trimmed with a knife, in order to make them all of the same length.

COLOUR.—X.

By Professor CHURCH, Royal Agricultural College, Cirencester.

CAUTIONS AS TO THE TRUE PRIMARY COLOURS AND CHROMATIC EQUIVALENTS—MODIFICATIONS OF COLOUR BY ILLUMINATION—DIFFUSED DAYLIGHT—LIGHT OF THE SKY AND CLOUDS—SUNLIGHT—A DOMINANT COLOURED LIGHT—ARTIFICIAL LIGHTS—TWO LIGHTS.

BEFORE entering upon the consideration of the changes produced in coloured objects by the nature of the light which falls upon them, it is desirable to repeat a caution which we have given our readers more than once as to the value to be put upon our supposed set of three primary colours and their chromatic equivalents; for, in discussing the laws of harmonious assortments of colours, we have assumed the truth of both those doctrines, because we were dealing with pigments or dyes, and not with coloured lights (see Lessons VI., VII., and VIII.), while for pigments, the conclusions reached by [illegible] rally adopted, so far as regards the relations and equivalen[illegible] of colours, are of no small service. Field's conclusions we[illegible] indeed obtained by imperfect methods, and relate, so far [illegible] they are true, only to colours produced by absorption; but [illegible] is, of course, precisely with this mode of producing colours th[illegible] we are concerned when occupied with pigments. It will [illegible] well, however, to point out the special convenience of the primary triad of colours in general use by painters and ornamental colourists. Yellow, red, and blue have been selected, for artistic as well as practical reasons. With these colours, unmixed, but properly distributed over a painted surface, it is perfectly possible to get that kind of "neutralised bloom" which all satisfactory colour-combinations should exhibit when viewed at a sufficient distance; just as a similar result may be secured by the mingling, through rotation or otherwise, of the same three colours. A second artistic or æsthetic reason for the selection of this triad lies in the variety thus secured. Yellow represents to the eye nearness, lightness, and brilliancy, and does not actually admit of anything like the intensity of the purest red. Red imparts an idea of warmth and richness, and is as far removed, in its several qualities and the sensation it awakens, from yellow as it is from blue. Blue gives us the element of coolness and retirement, and is less brilliant and more intense even than red. If we take the triad red, green, and blue, we have not the same range of effect at our disposal, red and green being removed from each by a far greater interval than that which separates green and blue. As to the practical uses of the two rival triads, there can be no hesitation in preferring the common one; for red and green pigments when mixed do indeed produce grey, and blue and yellow pigments, green; though were lights, not pigments, concerned, red and green would yield a yellow, and blue and yellow a white light.

We have already explained how the mixed nature of the rays reflected and absorbed by pigments causes this difference, this departure from the anticipated result; but the only thing we have to do under the circumstances is the adoption, for the special purpose, of a plan of mixing colours which can be successfully carried out in practice. The impressions which the retina of the eye receives, and which become translated by the brain into sensations of colour, are certainly produced in different ways. The mingled rays, for example, of red and bluish-green light produce a colour-sensation absolutely identical with that produced by the perfectly simple and pure yellow light of the spectrum; but it would be grossly incorrect to regard yellow as of necessity a compound colour for this reason, since we know it to be incapable of any kind of decomposition as it occurs in the solar spectrum and in most pigments. It is quite possible, also, to produce the colour-sensation of blue by the mingling on the retina of certain green and violet rays, yet this does not warrant us in regarding the solar blue rays as being otherwise than simple. But when we come to mix pigments on a palette we find that very different results occur, yet that in no case is a pure yellow, or red, or blue colour produced by any mingling of other colours. So our practical treatment of the colour-relation of pigments must differ from that of coloured lights.

We are also compelled to lay but little stress on the doctrine of chromatic equivalents. When pure coloured rays are experimented with, it is possible to learn the proportions in which they must be mingled to produce certain effects; but when the same problem is attempted to be solved in the case of pigments, the complexity of the subject baffles us, and our results are scarcely more than very rough approximations to the truth. Still, there is an obvious propriety in the more sparing use of luminous and brilliant colours, as yellow, as compared with those of great depth and intensity, such as blue; and if we find that mixtures in certain proportions of particular coloured pigments give colours approximating to certain standards, or produce neutral greys, we may consider such proportions as corresponding in some measure to the chromatic equivalents of the pigments in question. Thus it is found by experiment that two grains of nickel in the form of chloride yield a bluish-green solution, which is perfectly competent to neutralise the rose-pink colour of a solution of chloride of cobalt containing one grain of cobalt. In this instance, the nickel-green is related to the cobalt-pink in the proportion of 2 to 1. We trust that, without further dwelling upon these subjects of the primary colours and chromatic equivalents, we have said enough to show at once not only the use of our explanations in Lessons VIII. and IX. of colour-proportion, balance, and harmony, but also the reserve under which these explanations must be accepted. In passing on to the study of the modifying influences of different kinds of illumination upon the colours of objects, we would premise that the remarks just made must likewise be kept in view.

The quality and intensity of the light by which objects and their colours are discerned are liable to great variations, and produce corresponding changes in the colours reflected from the surfaces which they illuminate. Putting on one side, for the present, the variations produced by the nature of the substance or surface on which the light falls, we may consider the condition of a plane and uniformly-coloured surface as illuminated by

1. Diffused daylight, and sunlight;
2. A dominant coloured light;
3. Artificial lights, as candles, lamps, fire;
4. Two lights, of different quality or intensity.

§ 1. It is scarcely necessary to state that the light of day varies greatly in colour; the causes, however, of its variations may not be at once apparent. In reality, there is one chief active cause which originates its chromatic changes—*the air is not perfectly transparent*, it is more or less cloudy or troubled. Now even if the sun's luminous rays be purely white, they will suffer change by passing through a cloudy medium. The ease with which they pass will vary with the more or less complete approach to transparency of the atmosphere and its depth. Let us study in succession the blue light of the sky, the apparently white light of clouds, and the reddish light of direct sunshine.

How does the blueness of an unclouded sky originate? We may best explain it by means of an experimental illustration.

Upon a sheet of black glass or a surface of black japanned metal, place a drop of milk, diluted, if necessary—which will seldom be the case—with a drop of water. The milk is a cloudy medium; its minute particles reflect certain rays of very short wave-length—those towards the more refrangible or blue end of the spectrum; therefore, by reflected light, a drop of milk on a dark background appears blue. So, through a delicate skin, and a series of translucent but not transparent membranes, the light reflected where the dark background of a vein filled with venous blood exists, is blue. So, also, the translucent, but not absolutely transparent tissue of the iris of the eye often reflects a blue light, there being in this instance also a background of a black pigment, but no real blue colouring matter whatever. The blueness of the sky has a similar origin. Against the dark background of infinite space, a translucent medium is placed; this medium is the atmosphere. It is never transparent, countless millions of minute particles, chiefly of water, being suspended in it. When these particles are of a certain degree of minuteness and uniformity, they arrest the free passage of white light; this they do by a peculiar kind of "interference" (see Lesson II.). Each minute foreign particle of water gives rise to two reflections, one on each surface—one external, on the anterior surface; one internal, on the posterior. These reflected rays, passing from air into water, and from water into air, suffer different retardations, and, on emergence, cause the usual phenomenon of interference, namely, the production of colour. When the particles thus affecting the incident light are sufficiently minute and sufficiently numerous, the proportion of reflected green, blue, and violet rays, which together give the colour-sensation of blue, predominates greatly over the red, orange, and yellow rays, with their longer undulations. Thus, the reflected light of the open sky is blue; but let the thickness of the reflecting layer, or the number of the reflecting particles increase, and the blueness of the light decreases, for the solar light, which has been deprived by the kind of reflection just described of a great proportion of its more refrangible rays of short vibration, has become yellowish, or orange-tinted, and is no longer capable of furnishing an excess of blue rays. From this cause we see that while the light of the zenith is a distinct blue, it becomes gradually of a less pronounced tint towards the horizon, where it would be white if other conditions did not there produce other modifications of the reflected light. This exquisite gradation of tone in the sky is often missed by unobservant painters, who think that the same mixing of some blue pigment will do to represent the colour of the whole sky shown in their pictures.

Now if the reflected light of the blue sky owes its colour to a sort of sifting of the solar rays, it will be rightly concluded that the transmitted light, deprived by this process of its green, blue, and violet elements, will partake more or less distinctly of the colours of the residual rays of the solar spectrum. Such is the case. The light *transmitted through* a turbid medium shows a predominance of yellow, orange, or even red light. Direct sunlight partakes of this character, but it is generally more distinctly seen when the same object is illuminated by two lights, which can be compared and contrasted together. Yet there are cases in which the redness of sunlight is manifest enough. Not only is bright sunshine spoken of by painters as warm in an artistic sense, because of its ruddiness, but the light of the sun, transmitted through a great thickness of a turbid atmosphere, often appears, as at sunset, of an intense red or crimson colour. The street lamps in a fog illustrate, by their gradually increasing redness as they become more distant, the same fact.

While, then, the light reflected from the sky is bluish, and that transmitted directly from the sun through an aqueous atmosphere reddish, the light of day is often white. The particles suspended in the air may be either too large or too small to produce the effect we have been discussing. Thus, through certain kinds of fog and mist the light of the sun reaches us, reduced in intensity it is true, but unchanged as to its quality of whiteness. So, also, the light reflected from dense masses of cloud is often nearly white, and at other times is grey, owing to a comparatively deficient illumination or to absorption. It will not be necessary to detail here the modifications of colour which objects undergo when illuminated by direct sunshine, or by the light reflected by the blue firmament or white clouds, as it may be readily learnt from the next succeeding paragraph, in which we treat of the effects of a dominant coloured light.

§ 2. When a landscape is viewed through a piece of neutral-tinted or grey glass, the rays of different colours belonging to different parts of the spectrum are intercepted to a nearly equal extent; when the glass itself is coloured, a different result ensues. Through a yellow glass, all objects acquire a yellowish tinge, not because the yellow glass actually adds any yellow rays to the light which it reflects, but because it cuts off the other coloured constituents of the light in different degrees, and so increases the proportion of yellow light conveyed to the eye. Objects which are originally yellow remain virtually unchanged, but relatively intensified; those which are red lose a small part of their red rays; those which are green assume a yellowish-green hue, since some of their green and blue rays are cut off; while blue objects acquire a greyish-green hue, owing to the suppression of many of their proper blue rays, and of the further sifting which the white light they reflect suffers. When, on the other hand, objects variously coloured are illuminated by a pure light of one colour, that is, monochromatic light, the results are different. All objects reflect naturally, if they have the opportunity, as in daylight they have, some white light; but when a pure coloured light is thrown upon objects usually distinctly coloured, they can either reflect no light at all, or only that which is incident upon them. But, in point of fact, when experimenting with coloured illumination of this kind, we have not to deal with pure red, or orange, or green lights. It will be most serviceable for the purposes of the practical application of our principles if we give some clue as to the modifications produced in the colours of objects by different qualities of light, in which certain rays severally preponderate, but, nevertheless, do not wholly constitute the light. Illuminated by a light in which yellow rays predominate, yellow objects become less distinctively yellow when put by the side of white objects, which then assume a yellow tint. Pale yellow gloves by the yellow light of a lamp are hardly to be distinguished from white gloves. Orange-coloured objects become, if anything, rather more yellowish in yellow light. Vermilion increases in brilliancy if the light be not very largely composed of yellow rays, but merely have them in preponderating number. Reddish and bluish violets become duller and redder, losing a part of their blue. Blue itself, when pale, becomes paler, and inclines towards a greenish blue; while dark and rich blues lose somewhat in intensity and purity. If, instead of white light tinged with yellow, we try the effects of yellow light accompanied by a small amount of white light, the effects are still more decided.

The following is, in the main Chevreul's list of the modifications experienced by various coloured surfaces, when viewed in coloured light nearly pure, or in a dim diffused light with an intense coloured direct illumination:—

Yellow	**rays**	**falling on**	*white*	**make it**	**appear**	*pale yellow.*
„	„	„	*yellow*	„	„	*orange-yellow.*
„	„	„	*orange*	„	„	*yellower.*
„	„	„	*red*	„	„	*orange-brown.*
„	„	„	*violet*	„	„	*brownish-violet.*
„	„	„	*deep blue*	„	„	*greenish-slate.*
„	„	„	*green*	„	„	*yellowish-green.*
„	„	„	*black*	„	„	*blackish-olive.*
Red	**rays**	**falling on**	*white*	**make it**	**appear**	*red.*
„	„	„	*yellow*	„	„	*orange.*
„	„	„	*orange*	„	„	*redder.*
„	„	„	*red*	„	„	*redder.*
„	„	„	*violet*	„	„	*reddish-violet.*
„	„	„	*blue*	„	„	*violet.*
„	„	„	*green*	„	„	*reddish-grey.*
„	„	„	*black*	„	„	*rusty black.*
Blue	**rays**	**falling on**	*white*	**make it**	**appear**	*blue.*
„	„	„	*yellow*	„	„	*green.*
„	„	„	*orange*	„	„	*plum-brown.*
„	„	„	*red*	„	„	*violet.*
„	„	„	*violet*	„	„	*reddish-violet.*
„	„	„	*blue*	„	„	*bluer.*
„	„	„	*green*	„	„	*bluish-green.*
„	„	„	*black*	„	„	*bluish-black.*
Orange	**rays**	**falling on**	*white*	**make it**	**appear**	*orange.*
„	„	„	*yellow*	„	„	*orange-yellow.*
„	„	„	*orange*	„	„	*reddish-orange.*
„	„	„	*red*	„	„	*scarlet.*
„	„	„	*violet*	„	„	*reddish-brown.*
„	„	„	*blue*	„	„	*greyish-orange.*
„	„	„	*green*	„	„	*greyish-green.*
„	„	„	*black*	„	„	*brown.*
Violet	**rays**	**falling on**	*white*	**make it**	**appear**	*violet.*
„	„	„	*yellow*	„	„	*brown, rather reddish.*
„	„	„	*orange*	„	„	*light greyish-red.*
„	„	„	*red*	„	„	*reddish-violet.*
„	„	„	*violet*	„	„	*deeper tone of violet.*
„	„	„	*blue*	„	„	*bluish-violet.*
„	„	„	*green*	„	„	*greyish-violet.*
„	„	„	*black*	„	„	*slightly tinged with violet.*
Green	**rays**	**falling on**	*white*	**make it**	**appear**	*green.*
„	„	„	*yellow*	„	„	*yellowish-green.*
„	„	„	*orange*	„	„	*greyish leaf-green.*
„	„	„	*red*	„	„	*brown.*
„	„	„	*violet*	„	„	*greenish-slate.*
„	„	„	*blue*	„	„	*bluish-green.*
„	„	„	*green*	„	„	*more intense a green.*
„	„	„	*black*	„	„	*dark greenish-grey.*

The above results were originally obtained by Chevreul by exposing pieces of coloured cloth to diffused daylight, and illuminating half of each piece also by the light passing through glasses of the several colours named. The effects are consequently partly due to contrast, and are only true for the special conditions of the experiments performed. They, however, give us some notion of the various directions in which different coloured lights affect the colours of objects already moderately illuminated by diffused daylight. On this point see further the statements given under § 4 below.

§ 3. In considering the effects on coloured surfaces of yellow light we have in point of fact considered the effects of the light of gas, oil lamps, and candles upon them, for all the ordinary kinds of artificial light possess a superabundance of yellow rays. This preponderance is less marked in the case of paraffin oils and solid paraffin candles, the light of which, though far from white, is not so yellow as that emitted by burning stearine or tallow. By the side of objects illuminated by direct daylight, which is, we know, slightly reddish, the light of a candle, though really yellow, may appear orange, while direct sunlight itself may, by contrast, appear positively violet or blue. Now the general results of the yellow illumination of artificial lights upon coloured surfaces may be learnt by reference to the table given above, but it may be interesting to give in fuller detail one particular and familiar instance of the sort of effect thus produced. We allude to the strange effect of artificial light in altering the colour of certain violet colours, and of blues which possess a tinge of violet. Take as an example the precious stone known as the amethyst. A good specimen of this mineral presents by daylight almost the same tint as that of the flower of the violet, but at night, illuminated by lamp or candle-light, it loses much of its blueness, and acquires so distinct a reddish hue that it might be mistaken for a red garnet or carbuncle. This change is due to the deficiency of blue in the artificial light, while ordinarily the red of these stones is annulled partially by the greenish-blue element of daylight. A similar instance of a change in colour has been observed with some sapphires. The *saphir merveilleux* in the Hope Collection, South Kensington Museum, presents a clear blue tint by daylight, but by candlelight it appears violet. Certain flowers show a still more curious property. The flowers of the viper's bugloss (*Echium vulgare*) and of the marsh forget-me-not (*Myosotis palustris*) are rose-coloured in the bud and when they begin to open, but afterwards, on fully expanding, become blue as viewed by daylight. By artificial light, however, the change appears not to have taken place, at all events, to any great extent, since a spray of one of these plants thus seen by candlelight shows its buds red or rose-coloured indeed, but its fully-opened flowers are not blue, but only pink or a pale purplish-red. The difference between red and a blue verging on purple is thus partially annulled. So, also, as regards blues and greens; the ordinary green and blue pigments, with very few exceptions (*e.g.* aniline green), are hard to distinguish by candlelight. Those blues which verge on green do so, of course, by the special absorptive power which they possess for the yellow, orange, and red rays, and their power of reflecting the green, the blue, and the violet. Now, as candlelight is deficient in blue and violet, the green of these blue pigments then comes out in unusual force. Such serious changes are experienced by some blues under artificial illumination that it is often advisable to substitute green for blue in colour-combinations which are to be viewed at night by gas or candles. The triad *red—yellow—green* becomes under such circumstances superior in effect to the triads *red—yellow—ultramarine blue*, and *crimson—yellow—Prussian blue*. So yellow, to be seen well and effectively by candlelight, must incline towards orange or a golden hue; but white, on the other hand, if it be meant to appear white, must by no means be tinted with a shade of blue, with the intention of purifying it, and neutralising the yellowness of the illumination on the material. This plan in daylight is effective, but by candlelight dulls the brilliancy of the white, by the absorption of certain rays of light which it causes.

§ 4. A double illumination, where the lights are of different quality, produces some striking effects of contrast. Such effects are often seized upon and reproduced, within varying degrees of fidelity, by those artists who delight in painting forges, candlelight scenes, and conflagrations. In order to study the conditions and effects of double illuminations, the following experiment may be made. Place a sheet of pure white paper in such a position that it may be illuminated at the same time by diffused daylight and by the light of a candle. Now arrange an opaque rod vertically, so that it may throw two shadows upon the paper. The shadow thrown by the daylight will be tinged with yellow, while that produced by the candle will be bluish; the doubly illuminated surface being itself white. Now we have before pointed out (see § 3 above) that candlelight possesses a superabundance of yellow rays, and is therefore more yellow than the light of day. In consequence of this, the shadow of the rod, as cast by the light of the candle, and illuminated therefore only by candlelight, appears yellow. Conversely, as the light of day is bluish compared with that of a candle, the shadow of the rod as cast by the light of the day, and illuminated therefore only by daylight, appears blue. Of course the contrast between the colours of the two shadows is enhanced in accordance with the laws of contrast, as previously pointed out in Lessons V. and VI. Similar results are met with every day in the case of objects illuminated at the same time by a natural and by an artificial light. The lamps of a church may illuminate some parts of the furniture and floor with a yellowish light, overpowered and contrasted in other parts by the apparently purplish light of day. A remarkable effect of this kind is seen when strong sunlight illuminates a room through a window partly screened by a yellow or buff-coloured blind. Here the contrast and relativeness of the colours seen become very distinct. The light transmitted through the material in common use for blinds of this sort is of an orange tint, and it will be seen that the direct rays, escaping filtration through this medium, are of a beautiful reddish-purple colour. More complicated effects of the same nature may be observed in the case of stained glass windows. The simplest case of this kind that we can recall just now is, perhaps, that of windows glazed with a pale greenish glass, but bordered with strips of white glass, when the latter will appear pinkish under some conditions of natural illumination. The effect here is, of course, not wholly due to the proper or intrinsic colour of the daylight, but to the effect of complementary contrast between the white glass admitting the natural rays almost unaltered, and the greenish glass which very materially affects them. But the most magnificent and beautiful effects of this order are to be watched in the phenomena of sunrise and sunset. When a range of distant mountains is seen against the sky about the time of sunset, the effects produced may be readily explained. If the sun be sinking behind the mountains, the shadows which it casts will be illuminated moderately by scattered and reflected lights of a blue or bluish-violet hue, produced by the minute particles disseminated throughout the atmosphere. These hues will be to a certain extent real and objective, derived from the peculiarity of the light itself, and the colours of the objects and surfaces which it discloses. If these objects be grey, as many rocks, or white, as snow, then the blue or violet hue will be distinct, but it may be modified by the local colouring of the rocks or trees of the landscape. Still further, it will be changed or intensified by subjective contrast with the colour of the sky, for the light from the sky will reach an observer modified by its passage through a turbid medium, the air, and it will thus be yellow, orange, or red, according to the amount of blue, or more refrangible rays, which it cuts off. So the sky near the western horizon will often be of an apple-green colour, with clouds of greyish-purple edged with scarlet, all these variations being produced by the decomposition of solar light by its passage through a medium which is not perfectly transparent, and the consequent conveyance to the eye, in varying proportions, of lights of higher refrangibility which have been reflected, and of lights of lower refrangibility, which, escaping complete absorption, have been transmitted.

Hitherto we have regarded the colours of objects as they are modified by the quality of the light which falls upon them. We have to study in the next place the influence of the structure, surface, and material of the objects themselves upon their apparent colours.

MINING AND QUARRYING.—III.

By George Gladstone, F.C.S.

COAL.

DIFFERENT KINDS OF COAL—ANALYSIS—HEATING POWER—ILLUMINATING POWER—BORING FOR COAL.

Although by far the greater part of all coals consists of carbon, the various kinds of coal possess very different qualities; and it is necessary to keep these distinctions in mind in order to select the most suitable description for any given purpose.

At one end of the series is the anthracite or non-bituminous coal, and at the other extreme the cannel, which is used for making gas and illuminating oils. Between these are several varieties more or less bituminous.

Anthracite is principally met with in the western portion of the South Wales coal-field, and in Ireland; but it occurs to a limited extent in other districts. It is very hard and heavy, and is often called "stone coal." The specific gravity is about 1·37, being about the heaviest coal known, excepting impure specimens containing a large proportion of mineral matter. The consumption is not very large, as it will not burn in open grates. It is used in some factories because it gives off little or no smoke; but it requires so strong a draught, and only burns at such a high temperature, that it is very destructive of the furnace-bars. In the Swansea valley it has been used for iron-smelting, and on account of its general freedom from sulphur is very suitable for the purpose; but even in the blast furnaces it does not burn readily. The Pembrokeshire anthracite is highly prized by maltsters, to whom a coal perfectly free from smoke and sulphur is most important.

The semi-bituminous or steam coals come next in order. They do not light up readily, but they contain a large percentage of carbon, and give out a great deal of heat in proportion to their bulk. The best South Wales descriptions have also the advantage of making but little smoke; but they are more tender, and will not bear shipment to hot climates so well as the Newcastle steam coal. The hard splint coal of Scotland may be classed with these. In many places the latter is employed by iron-smelters without being first converted into coke.

The free burning or bituminous coals are the most familiarly known. They burn brightly in an open stove, and are approved as the best household coals. They give out a yellow flame, and a considerable amount of smoke, but do not produce so much heat as the preceding. They often cake together as they burn, and yield an excellent coke.

The last in the series are the cannel coals. They occur principally in the Scotch, Lancashire, and Flintshire coal-fields. Unlike other descriptions they break with a conchoidal fracture, and more resemble an opaque blackish resin than a true coal. When set fire to they flare up with a whitish flame, and have been used as a substitute for candles—hence the name. The best descriptions of cannel are the lightest coals known in this country, the specific gravity of the Boghead being as low as 1·15. They are used in gas-works, being very rich in hydrocarbons. By distilling at a lower temperature, they yield paraffin, benzole, and illuminating oils, as well as a variety of other useful products.

It may generally be put down that if heat be the object desired, the coal most suitable will be that which is richest in carbon; but if illuminating power be required there must be a certain proportion of hydrogen in combination with the carbon. These are not the only considerations, however. No coal consists simply of these two substances. There is always more or less mineral matter, which is generally useless, and often deleterious. Sulphur is a very common ingredient. On examining minutely almost any coal, small specks or threads of a bright yellowish mineral may be detected, called *brasses* by the miners. They are pyrites, or sulphuret of iron. The worst pieces are picked out when the coal is brought to the pit's mouth, but sometimes they escape notice. In an open fire they split with considerable violence, and are thrown out, or produce the disagreeable sensation of burning sulphur. In a close furnace they exercise an injurious effect on the ironwork and furnace-bars. It is still more objectionable in gas-works and blast-furnaces. In well-regulated establishments, therefore, it is customary to analyse the coals, not merely for the sake of calculating their heating or illuminating power, but also to ascertain precisely the amount of sulphur they may contain. For use on shipboard economy of space has also to be considered, as well as heating power; and a very extensive series of investigations has been made for the Admiralty, in order to determine which coals are best suited for Her Majesty's steam navy.

The following analyses, taken from the Admiralty lists, will serve as specimens of good steam coals, an anthracite being put at the bottom of the table by way of comparison :—

Name of Coal.		Specific Gravity.	Carbon per Cent.	Hydrogen per Cent.	Nitrogen per Cent.	Oxygen per Cent.	Sulphur per Cent.	Ash per Cent.
Ebbw Vale		1·27	89·78	5·15	2·16	0·39	1·02	1·50
Duffryn		1·33	88·26	4·66	1·45	0·60	1·77	3·26
Nixon's Merthyr		1·31	90 27	4 12	0·63	2·53	1·20	1·25
Graigola		1·30	84·87	3·84	0·41	7·19	0·45	3·24
Llangennech		1·31	85·46	4·20	1 07	2·44	0·29	6·54
Average of South Welsh		1·30	87 73	4·39	1·14	2·63	0·94	3·16
Haswell		1·28	83·47	6·68	1·42	8·17	0·06	0·20
West Hartley		1·26	81·85	5·29	1·69	7·53	1·13	2·51
Buddle's West Hartley		1·23	80·75	5·04	1·46	7·86	1·04	3·85
Hasting's Hartley		1·25	82·24	5·42	1·61	6 44	1·35	2·94
Carr's Hartley		1·25	79·83	5·11	1·17	7·86	0·82	5·21
Average of Newcastle		1·25	81·63	5·51	1·47	7·57	0·88	2·94
Ince Hall, Pemberton	Lancashire.	1·27	77·01	3·93	1·40	5·52	1·05	1·09
Rushy Park		1·28	77·76	5·23	1·32	8·99	1·01	5·69
Elsecar	Derbyshire.	1·29	81·93	4·85	1·27	8·58	0·91	2·46
Staveley		1·27	79·85	4·84	1·23	10·96	0·72	2·40
Elgin	Scotch.	1·20	76·09	5·22	1·41	5 05	1·53	10·70
Kilmarnock		1·24	79·82	5·82	0·94	11·31	0·86	1·25
Bagillt, North Wales		1·27	88·48	5·62	2·02	0·86	1·36	1·63
Welsh Anthracite		1·37	91·44	3·46	0·21	2·58	0·79	1·52

Of the South Wales coal it will be remarked that their specific gravity is high, that the first three are superior to the other two in quantity of carbon; but that while the two latter are deficient in this respect, and leave too much ash, they have the advantage in freedom from sulphur. Of the Newcastle descriptions the Haswell gives the best results. Of the miscellaneous list the Elgin appears the worst, having a low specific gravity, and an unusual quantity of ash, which indicates a low heating power. The Rushy Park, too, has an excess of incombustible matter.

An analysis, however, is not sufficient of itself to settle the relative merits of different coals; and accordingly an experimental boiler was set up in which they were practically tested. The following are the average results arrived at—A being the number of pounds of water evaporated by one pound of fuel; B the number of pounds of water evaporated per hour; C the number of cubic feet occupied by a ton of coal; D the per-centage of large coals :—

Coal.	A.	B.	C.	D.
South Welsh	9·05	448·2	42·71	60·9
Newcastle	8·37	411·1	45·30	67·5
Lancashire	7·94	447·6	45·15	73·5
Scotch	7·70	431·4	49·99	73·4
Derbyshire	7 58	432·7	47·15	80·9

From these figures it appears that the South Wales coal is best in respect of evaporating power, but worst in point of durability. The last column is of particular significance when coals have to be sent out to distant naval or mail packet stations, as they frequently lie there for many months exposed to the weather, during which time a tender coal will crumble away so much as to be almost worthless; the result being that it either chokes up the furnaces or passes through the fire-bars before it is entirely consumed.

In dealing with the cannel coals, the principal points to be considered by the analysts are, the amount of volatile matter, and the freedom from sulphur. The following are specimens of some of the best from the Scotch coal-fields :—

Cannel Coal.	Volatile Matter per Cent.	Sulphur per Cent.
Boghead (brown)	71·06	0·24
Do. (black)	62·70	0·35
Torbanehill	67·11	0·32
Leshmahagow (Auchinheath)	56·23	0·55
Do. (Southfield)	49·34	1·35

In actual product of illuminating gas, some of the principal English and Scotch coals may be enumerated :—

Scotch.	Boghead	15,000	cubic feet of gas per ton.
	Leshmahagow	13,500	,,
	Capeldrae	14,400	,,
	Wemyss	14,300	,,
Lancashire.	Wigan	11,400	,,
Newcastle.	Pelton	11,500	,,
	Pelaw	11,500	,,
	Pelaw Main	12,400	,,
	Gosforth	10,000	,,
	Dean's Primrose	11,100	,,

We must now turn to the various operations connected with coal-mining itself—an industry which, for many obvious reasons, when it is remembered that at present this country is the chief coal-producing country in the world, must always be attended, with peculiar interest to English readers. To the coal that lies in such vast masses under the surface of our soil must be attributed the chief share in raising our importance as a nation to its present height, for without it we could never have attained the eminence we now possess as a manufacturing country, or have been able to utilise other valuable sources from which much of our wealth is derived.

The first step is to explore the ground, in order to ascertain what seams there are, their course, thickness, and whether disturbed by faults (or troubles, as they are often called by the miners). Upon a careful determination of these points much of the future success of the colliery depends. In hilly districts, or where the strata are very highly inclined, the seams may be sometimes traced at the surface, and a very slight excavation will be sufficient to enable one to calculate the angle of dip of the beds. So far the investigation is easy enough, but it does not follow that it continues uninterruptedly, or in the same plane through the mountain. In the more ordinary instances the coal seams are some distance below the surface, and they can only be mapped out by an elaborate system of borings.

Fig. 6 is an imaginary section of a coal property. The strata have a general dip from east to west of about 1 in 5; but the position of the coal seams, represented by the letters A, B, C, D, has yet to be ascertained, in order to determine whether they are worth working, and which would be the best point for sinking the shaft. A trial by boring might be commenced at No. 1, and at a depth of say forty fathoms the double seam A would be pierced through. Calculating the dip at 1 in 5, this seam, then, should crop out at the surface at about 200 fathoms east of No. 1. In order to make pretty sure of cutting the same seam again, allowances must be made for any difference in the level, and for broken ground at the surface, so that the next bore would be made at a somewhat less distance, say at No. 2. This one realises the expectation of the borer: it cuts the double seam A near the surface, and at about sixty fathoms it comes upon another seam, B. The ground is thus proved to be regular between these two borings, and B may be inferred to pass under No. 1, at a depth which can be easily calculated. A third boring would then be commenced at 3, with the expectation of cutting B near the surface; but here the workman is disappointed, and he bores down for about sixty fathoms, when he comes upon a thick coal seam, C, evidently a different one from either of the others hitherto discovered. He knows by this that there is a dislocation somewhere between 2 and 3. Again he tries at 4. At first he passes through rock of the same character as that overlying C, but suddenly it changes, and he finds himself again in unknown ground; but boring on he comes to another double seam, D, apparently not the same as A, the size of it and the nature of the accompanying rock both being different. He tries again at 5, and cuts the seam D at a lower level than he ought by calculation, while, it will be observed, he has missed C altogether. These five borings, then, will not be sufficient to enable the borer to make a complete section of the strata, but he has, nevertheless, ascertained the principal features. Having struck D twice, he can calculate where C will be found between 4 and 5. He has proved that in the neighbourhood of 4 there is a downthrow of about twenty-five fathoms, though he does not know the precise angle of the fault. In like manner he knows that there is another somewhere between 2 and 3, but he has not ascertained its exact position or extent. Of the position of the seams C and D, to the west of this fault, he knows nothing at present. Practically the explorer usually gets a good deal of information from a study of the sections displayed in neighbouring collieries; and thus he may be able to complete the section, having by his own borings established so many points.

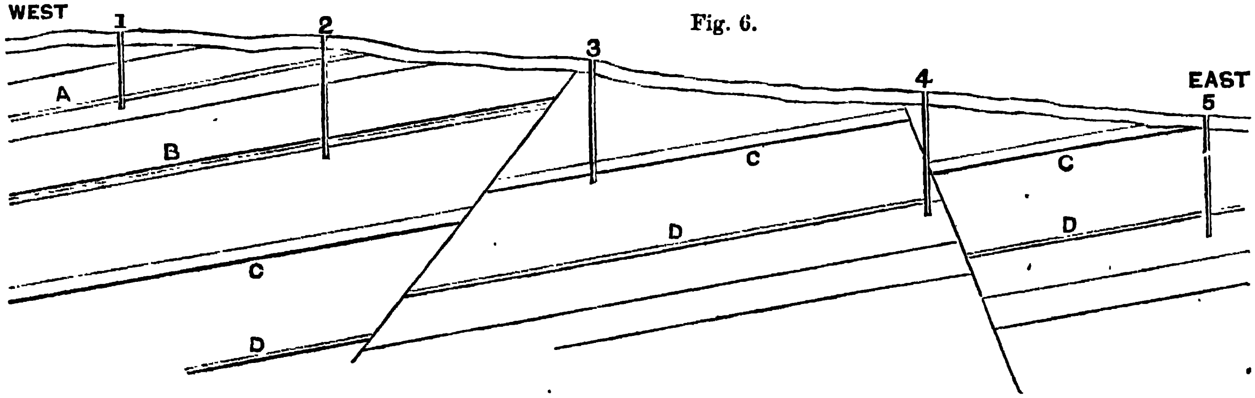


Fig. 6.

In the preceding instance, the plane of the stratification or line of dip is supposed to have been already known. But that has often to be ascertained, which is done by making the third bore at such a point as will form with the two others an equilateral triangle (see Fig. 7). Suppose the coal seam at A is five fathoms lower than at B, and at C is only four fathoms lower than at B, the borings being at 100 fathoms' distance from one another; extend the line B C to D. Then as the difference between the respective depths of B and C (four fathoms) is to the distance between them (100 fathoms), so is the difference between the depths of B and A (five fathoms) to x, a point on the line B C D. As 4 : 100 : : 5 : x or 125 fathoms from B. At x, then, the depth will be the same as at A; a line joining these two will be upon the level or plane of stratification, and the true dip will be at right angles.

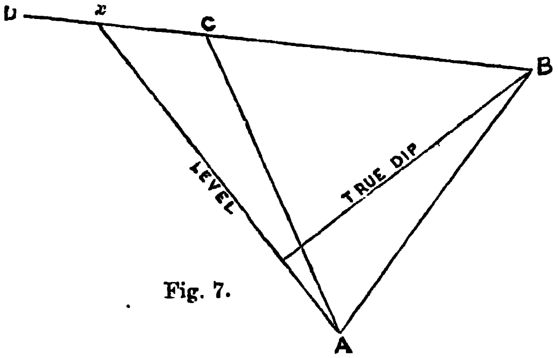


Fig. 7.

It is the object of the borer so to arrange his work as to gain as much information as possible without going to a great depth, as the cost per fathom increases rapidly as you go deeper. One boring of eighty fathoms is more costly than three of forty fathoms each.

The tools employed, and mode of working, must now be described. The ordinary cutting instrument is a chisel of the best hardened steel fixed to an iron rod which can be lengthened indefinitely by screwing on other rods as required, each joint being provided with a male screw at one end and a female at the other, the top joint of all having a head to it through which a cross-bar is passed. The workmen take the cross-bar and go round and round, by which means the chisel gradually cuts away the stone, and the rod sinks deeper and deeper in the bore-hole. At first the work is light, but with the addition of fresh joints the rod becomes very heavy, and the pressure has to be eased. For this purpose a pulley is fixed above the head, and a rope, attached to a windlass, is passed over the pulley and fastened to a ring in the head of the rod. This machinery also comes into requisition in drawing the rods, which has to be done periodically, in order to ascertain the nature of the rock which the bore is passing through. The sludger is partly hollow, and has a valve in the lower part, opening inwards, which receives the mud produced by the grinding of the chisel, and is thus brought to the surface. The samples thus periodically brought up are carefully preserved in bottles, and their depth recorded, experienced borers being able to tell from the appearance of the mud the character of the different strata they pass through. When approaching a coal-seam, this has to be constantly attended to, as it is only thus he can measure the thickness of a seam when he comes to one; and without determining that point accurately his explorations would be of little value. There are chisels and other tools of different shapes which are found necessary at times; and sometimes, especially in deep borings, the rod is liable to get bent or broken, in which case other implements have to be used to extract it, occasionally a matter of no little difficulty. The rods are usually made of the best tough Swedish iron, about an inch and a quarter in diameter, the edge of the cutting chisel being about three inches wide. The rods are made of uniform length, so that they serve as a measure of the depth of the boring.

The coal-field being thus tested, the next article will proceed to describe the plan to be adopted in opening out the mine.

THE STEAM-ENGINE.—IX.

By J. M. Wigner, B.A.

SINGLE-ACTING ENGINE—NON-CONDENSING ENGINE—DOUBLE-CYLINDER ENGINE—HORIZONTAL ENGINES.

The engine which we have described and figured in the last article, though not of the form most commonly employed, may be taken as the best type that could be chosen to exhibit the general principles on which all engines act; and for this reason it was described first. In the present paper we propose to consider the principal modifications of this type which are introduced into stationary land engines. Marine engines and locomotives will be noticed in a succeeding paper.

In this engine the piston, it will be observed, is moved in both directions by the force of the steam, which is admitted alternately to either end of the cylinder. It is therefore known as a double-acting engine, and nearly all engines are thus made.

In a few cases, however, the steam is only made to force the piston in one direction, and a counterpoise is affixed to the other end of the beam so as to draw the piston back again to the end of the cylinder from which it originally started. This was the kind of engine first introduced, but it has now quite gone out of use, except in a few special cases in which nearly all the work has to be performed while the piston is moving through the cylinder in one direction.

Many large pumping engines are of this class, and these are often required for raising water to supply towns, or in mining districts to keep the mines dry by removing the immense quantities of water which find their way into them from land springs.

In the latter case a series of cisterns are placed in the shaft of the mine above one another at intervals of about thirty feet, and a pump forces the water from each of these into the one above it. These pumps are usually made with heavy solid plungers which are raised by the engine, and then fall by their own weight, thus forcing up the water. In this way all the strain on the engine is during the interval that the pump-rod, to which all the plungers are attached, is ascending: a single-acting engine, therefore, will answer every purpose.

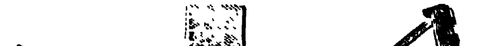


Fig. 35

Fig. 35 gives us a sectional view of an old form of engine of this class, and shows its action. The beam-ends here are arched, and the rods connected by chains, this being the usual plan before the invention of Watt's "parallel motion." After the description of the double-acting engine in our last paper, the way in which this is driven by the steam will very easily be understood without any lengthened description. T represents the pipe by which the steam enters from the boiler, and when the valves are in the position shown in the figure it acts directly on the upper side of the piston, forcing it down, and thus raising the pump-rods and the counterpoise Q, which are attached to the other end of the beam B B.

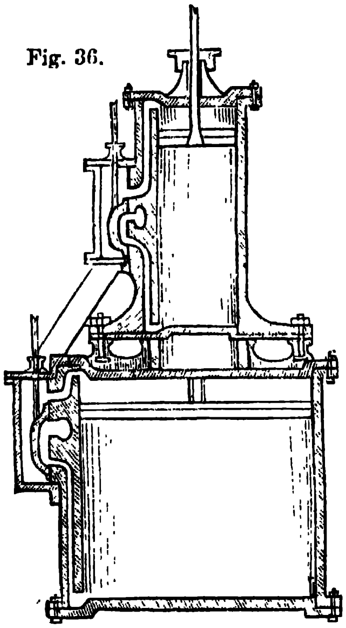


Fig. 36.

All the valves are tappets, and are attached to the valve-rod *d*, so that they all move simultaneously. The rod *d* is jointed near its centre to a bent lever *d c k*, hinged to a support at *c*; the end *k* is made into a ring through which the tappet-rod F passes, and the tappets *b* and *a* on this move the lever at the right moments. There are three valves on the valve-rod; the upper one, *m*, regulates the entry of the steam to the upper end of the cylinder; the lower one, *o*, governs the communication of the lower end with the condenser, N; while the middle valve, *n*, serves to establish a communication between the two ends of the cylinder, and is known as the equilibrium-valve. In the position shown *m* is open, so that the steam is pressing the piston down; *o* is also open, and through it the lower end of the cylinder communicates freely with the condenser. When the down stroke is nearly completed the valve-rod is lowered by means of the stud *b*. The result of this is that *m* and *o* are both closed, so that the cylinder is now cut off from both boiler and condenser. The equilibrium-valve *n* is, however, opened, and by means of this a free passage is made for the steam to pass from the upper end of the cylinder to the lower. By this all steam-pressure is removed from the piston, and it is left perfectly free; the weight of the rods and counterpoise, therefore, raise it again to the top of the cylinder. In doing this the valve-rod *d* is raised by the lower tappet, and thus the steam is again allowed to act on the piston, and causes it to make another descent, and in this way the motion is sustained. The weight of Q is, of course, made to bear a due proportion to that of the piston and rods; in some cases the rods are quite heavy enough without any counterpoise at all, and it is then dispensed with. No fly-wheel is necessary in this case; it would, in fact, be a hindrance rather than a help, since the action of the engine is not uniform, nor is it required to be so.

Though single-acting engines are frequently used for pumping purposes, we must not imagine that none but these are so employed. Many of the better pumps are made double acting, so that the water is raised during each stroke of the plunger, and with these a double-acting engine is, of course, required. A fly-wheel is, however, unnecessary, since there is no special need for any uniformity of motion. Some of the largest engines in the world are those used in Cornwall for drainage purposes in connection with the extensive mining operations carried on in that locality. In these engines, as a rule, economy of fuel is carried to the greatest extent possible. This partly arises from the plan already alluded to of registering and publishing statements of the work accomplished by each engine as compared with the fuel employed, and partly from the fact that they are worked with steam at a very high pressure, and cut off at an early part of the stroke. This, of course, produces some irregularity in the movement, but with a pumping engine this is by no means material.

Both the engines we have described are condensing, or, as they are frequently called, low-pressure engines. The latter term, however, is not strictly accurate, since condensing engines are very frequently worked with steam at a high pressure. The strict division is into condensing and non-condensing engines, but the other terms are frequently used, and if we bear in mind that they are used almost synonymously no inconvenience will arise.

Considerable saving is, as we have seen, effected by the use of a condenser, since nearly the full pressure of the steam is transmitted to the working beam, and thus to the machinery. The advantage produced, however, is not all clear gain, since the condenser with its attendant pumps occupies much space, and thus adds considerably to the prime cost of the engine. Besides this, too, a certain portion of the power of the engine is consumed in imparting motion to the cold water and air pumps.

In many cases the space available for an engine is but limited, and then the additional room required for the condenser and its arrangements is a serious drawback. Hence we find that very often this part of the engine is entirely omitted, and the steam, instead of passing from the exhaust into the condenser, is allowed to escape directly into the air. The first consequence of this is clearly a considerable loss of power, for the exhaust side of the piston is now exposed to the air, which thus is allowed to exert its full force on the side of the piston opposite to that on which the steam is pressing, and this force has to be overcome before the piston can be moved. The working force, therefore, is only the excess of the steam-pressure over that of the air—that is, a deduction of nearly 15 pounds per square inch has to be made from the pressure of the steam when calculating the actual power produced.

It is clear from this that in non-condensing engines steam must be employed at a higher pressure than is required in one that has a condenser. The least pressure that will suffice is about 20 or 22 pounds, and nearly always it is considerably greater than this, for as the pressure increases the proportional loss caused by the opposition of the air becomes less. In most instances, however, the smaller bulk and greater convenience of a non-condensing engine render it the most advantageous form. The steam, when it escapes from the exhaust, is, however, often utilised in some way so as to prevent the total loss of the heat which is stored up in it. Sometimes it is employed to warm the feed-water, or to heat a drying closet, or in many other ways.

Some large engines are now constructed with two cylinders, one of which is worked at a high, and the other at a low pressure. In these cases the steam first enters the high-pressure cylinder, and having accomplished its work there, passes through the exhaust to the other cylinder. This latter is fitted with a condenser, and thus the steam as it leaves the first has quite sufficient force to work the piston in the second. Fig. 36 represents one form which is sometimes given to an engine of this construction. The high-pressure cylinder here is firmly secured to the cover of the other, and the steam passes from the exhaust to the valve-casing of the lower cylinder by a pipe seen behind it. Sometimes both pistons are fixed on the same rod, a well-made stuffing-box being placed between the cylinders. This is, however, very awkward to get at when placed thus, and to obviate the difficulty, two piston-rods are often fixed to the lower piston. One of these passes on each side of the upper cylinder, which is of smaller diameter than the lower, and above it there is a cross-head to which all three piston-rods are fixed, and this imparts motion to the beam.

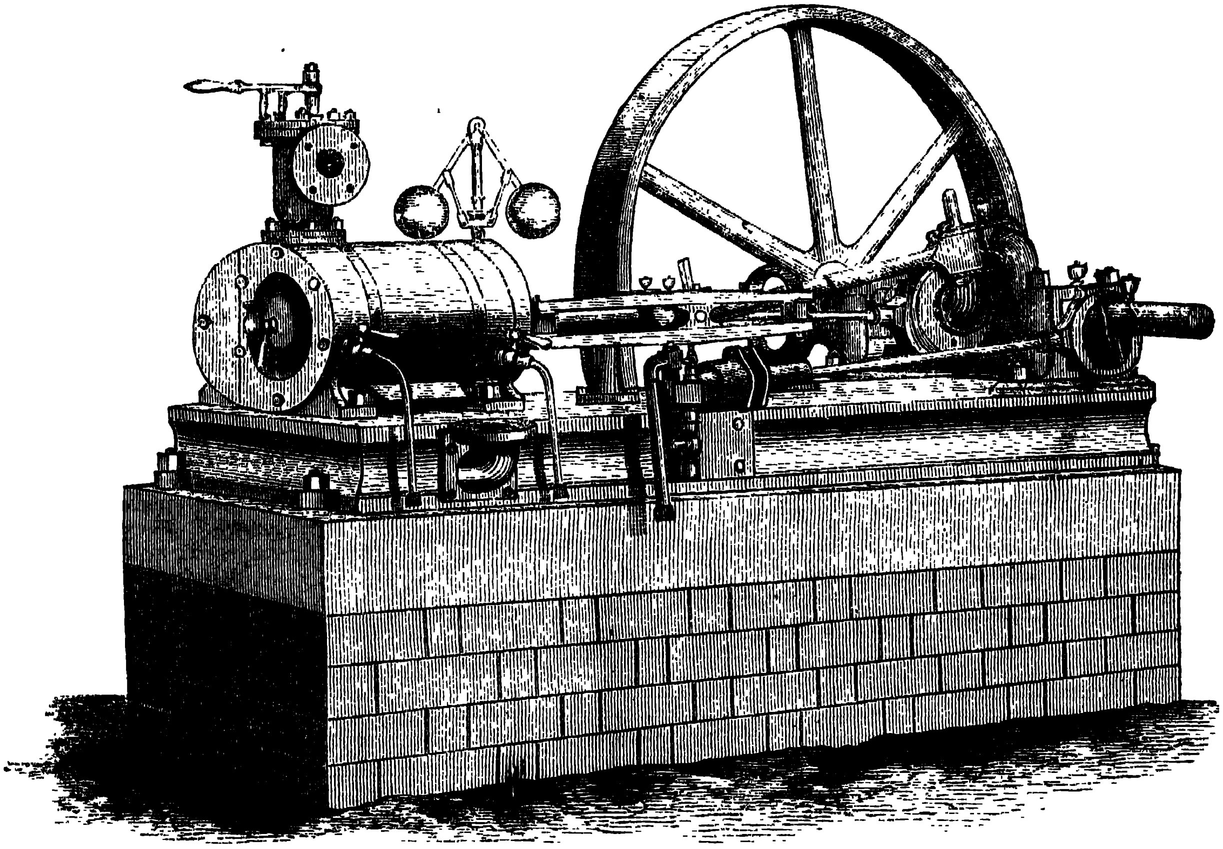


Fig. 37.—STEAM-ENGINE WITH HORIZONTAL CYLINDER.

The rods which work the slide-valves are likewise joined to a small cross-head placed above them, and thus both are worked simultaneously. In the engine here shown, two precisely similar valves are used, but in other forms the arrangements are so modified that a single compound valve governs the supply of the steam to both cylinders.

There is some diversity of opinion respecting the action of double-cylinder engines as compared with those which have but one. At the New River Waterworks near London, two engines were erected some time ago of the same power, but one fitted with two cylinders, and the other with only one. The performances of these have been carefully noted, and it is found that with a given expenditure of fuel, as nearly as possible the same amount of work is performed by each, so that it seems difficult to say which of these classes of engine is the more economical and satisfactory in its action.

The engines we have figured and described hitherto have all had a working beam, and this form is very frequently given to large stationary engines. It will, however, at once be seen that in many cases an engine of this construction would be quite inadmissible, since a large amount of room is occupied by it, and it cannot be moved at all from place to place. Besides this, in a small engine, the force expended in moving the beam would be a serious waste; hence in most engines it is altogether dispensed with. In those which do not condense the steam, a cold-water pump is manifestly unnecessary, and we have, therefore, only to make some arrangement by which the piston shall impart motion directly to the fly-wheel without the intervention of the beam, and also to provide for the boiler being duly fed with water.

Occasionally the fly-wheel is supported directly over the cylinder, a cross-head is then attached to the piston-rod, and made to move between guides so as to keep it in a perfectly vertical position, and a connecting-rod joins this to the crank. This is known as a "crank-overhead engine," but is not very generally used. Its great advantage is the little ground-space it occupies.

The most usual plan is to have the cylinder horizontal (Fig. 37), and fixed to one end of the bed-plate of the engine, while the axis of the fly-wheel is at the other end. The fly-wheel is then by the side of the bed-plate, and a slit is frequently cut in the floor to receive its lower portion. Here, as in the engine just described, a cross-head is fixed to the piston-rod, and slides between parallel slots in guide-plates secured to the bed, and thus lateral strain on the piston-rod is avoided. The connecting-rod is jointed with a pin to the cross-head, and by this and the crank the fly-wheel is put in motion. The eccentric is fixed, as usual, on the axis of the fly-wheel, and, by means of a rod, moves the slide-valve, and thus regulates the supply of the steam.

The governor balls are placed on a special support, and are driven by an endless band and a spur-wheel. The whole engine is, as will be seen from the figure, very compact. The smaller sizes are usually made with all the parts firmly fixed to one solid bed, and all that is requisite is firmly to secure this to the concrete or masonry on which it rests. Sometimes a feed-pump, driven by an eccentric or crank, is fixed to the engine; but in many cases, especially where a number of small engines are driven by steam derived from one boiler, some other plan is adopted, and not unfrequently a small steam-pump is provided specially to supply the requirements of the boiler.

PRACTICAL PERSPECTIVE.—VIII.

FIGS. 39, 40, 41.—The object of this study is a block of four stone steps, with a wall at each end carried up to the height of the upper step.

Of this object, Fig. 39 is the plan and Fig. 40 the end elevation—the wall in this being supposed to be transparent, so that the exact position of the steps beyond it may be seen.

Having found the vanishing-points and measuring-points, according to the angles at which the plan is placed, it is advisable, in the first place, to put into perspective the entire block, out of which the whole object is, as it were, hewn.

The student who has followed the course of lessons on Projection will have no difficulty in understanding that the end elevation A C *d* D would stand on the line A C of the plan, the line A D standing upright in A. Therefore at A′ in Fig. 41 draw the perpendicular A′ D, and from A′ and D draw lines to vanishing-point VP1.

From A′ set off A′ C′ equal to A C in Figs. 39 and 40, and from C′ draw a line to MP1, which, cutting A′VP1 in *c*, will give the place for the distant perpendicular *c d*, and this will complete the general form of the end elevation.

On the perpendicular A′ D mark off the heights of the steps—viz., 1, 2, 3—and draw lines from these points to VP1.

From A′ set off on the picture-line the lengths 1, 2, 3, representing the widths of the treads of the steps, and from these points draw lines to MP1, cutting A′ *c* in 1′, 2′, 3′.

At 1′, 2′, and 3′ erect perpendiculars, meeting the lines drawn to VP1 from 1, 2, 3 on A′ D, and these intersecting will give the inner and outer angles of the steps, F, G, H, I, J, K. Now from A′ D and *d* draw lines to VP2 (this vanishing-point is not shown in the plate, owing to want of space). From A′ set off on the picture-line A′ B′, equal to the length A B in the plan (Fig. 39).

From B′ draw a line to MP2, cutting the line drawn from A to VP2 in *b*.

At *b* draw the perpendicular *b e*, and from *e* draw a line to VP1, cutting the line drawn from *d* to VP2 in *f*; this will complete the general block.

From A′ set off A′ F, and from B′ set off B′ E, equal to the thickness of the wall—shown on the plan.

From E and F on the picture-line draw lines to MP2, cutting A′ *b* in E′ and F′.

At E′ and F′ draw perpendiculars, cutting D *c* in G and H. These will give the inner edges of the walls.

From K draw a line to VP2, which will give the edge of the top step; and from G and H draw lines to VP1, cutting K in *m* and *n*.

From I draw a line to VP2, cutting E′ G in *g*: this will give the front of the lowest step.

From *g* draw a line to VP1, and from F a line to VP2; these, intersecting in *h*, will complete the tread or upper surface of the lowest step.

At *h* draw a perpendicular, and from G draw a line to VP2, intersecting the perpendicular *h* in *i*. This will give the rise or front of the second step.

From *i* draw a line to VP1, and another from H to VP2; these lines will intersect in *j*, and thus complete the second step.

From *j* draw a perpendicular, and from I a line to VP2, cutting the perpendicular *j* in *k*.

From *k* draw a line to VP1, and from J a line to VP2. These, intersecting in *l*, will complete the third step; and a perpendicular, uniting *m* and *l*, will complete the projection.

EXERCISE 23.

Scale, ¼ inch to the foot. Height of spectator, 6 feet; distance, 18 feet

A plane square, the side of which is 8 feet, lies on the ground-plane, with one angle touching the picture-plane at 6 feet on the left of the spectator; its sides recede at angles of 55° and 35°. Give the perspective projection of the square.

EXERCISE 24.

Repeat the previous exercise, but show the figure divided (as for a draught-board) into 64 squares. Colour the divisions alternately.

EXERCISE 25.

Scale, ¼ inch to the foot. Height of spectator, 5 feet; distance, 15 feet

Put into perspective a cube, when one of the edges (4 feet in length) touches the picture-plane at 6 feet on the left of the spectator, and its sides recede at 45°.

EXERCISE 26.

In the same picture, at 5 feet on the right of the spectator, put into perspective a cubical figure 4 feet square at its base and 9 feet high, when one of its edges touches the picture-plane, and its sides recede at 50° and 40°.

EXERCISE 27.

The scale is ¼ inch to the foot, the height of the spectator is 6 feet, and the distance 18 feet.

Put into perspective the divided vertical square shown in Fig. 15 (Vol. I., page 365), when its plane is at 50° to the picture-plane.

*** The student is reminded that the lines which in the figure referred to are drawn to the centre of the picture, must in the present exercise be drawn to a vanishing-point on the right side, and that the lines drawn from I J and P, instead of being drawn to the point of distance, must be drawn to the measuring-point.

EXERCISE 28.

All the conditions being the same as in the last exercise, put into perspective the object shown in Fig. 16 (Vol. I., page 365), when the plane of the square side is at 40° to the plane of the picture.

EXERCISE 29.

Scale, ½ inch to the foot. Height of the spectator, 6 feet; distance, 18 feet.

Put into perspective the cross forming the subject of Fig 24 (Vol. I., page 388), when the point C′ is on the picture-line at 6 feet on the left of the spectator, and when the sides of the containing parallelogram C′ B and C′ E recede at angles of 30° and 60°.

EXERCISE 30.

Scale, height of spectator, and distance the same as in the last exercise.

Put into perspective the block of steps shown in Fig 23 (Vol. I., page 384), when the point B is at 7 feet on the left of the spectator, and when the object has been so rotated that the line B K recedes from the picture-plane at 50°.

⁂ Remember that the distances 1', 2', 3', A'' (Fig. 23) are found by means of the measuring-point, instead of the point of distance, and that all lines which are parallel to each other in the object converge to the same point.

The object of the next study is the same as that in Fig. 33—viz., a pyramidical roof, resting upon four square piers.

the centre of the picture as at C, and draw the perpendicular from it for the line of direction. It will be remembered that as this line represents not only the direction of the central ray, but the distance of the spectator as well, its length will be the same as that between the centre of the picture and the point of distance in Fig. 33.

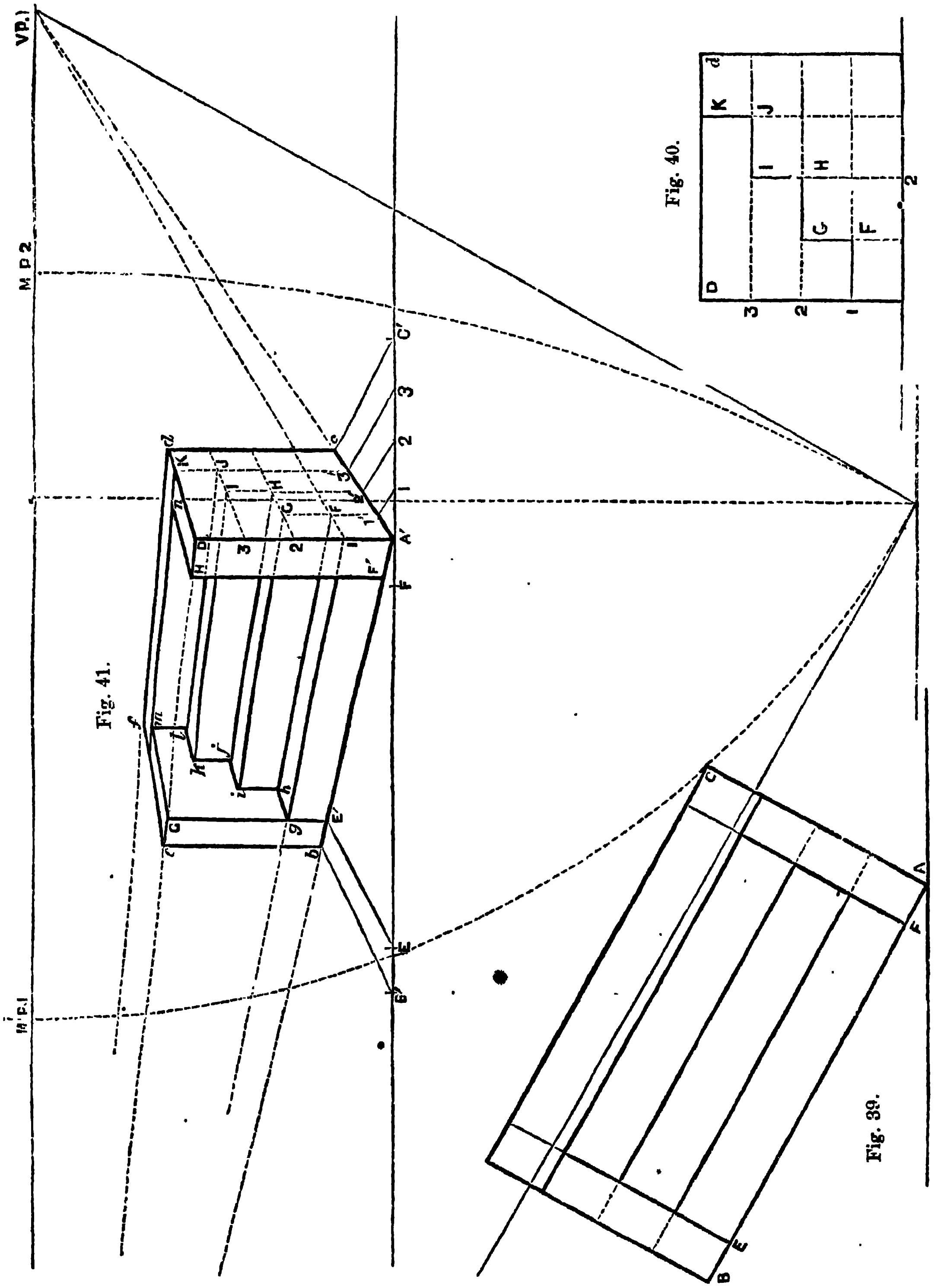


Fig. 40.

Fig. 41.

Fig. 39.

In the present case, however, the object is placed so that its sides are at certain angles to the plane of the picture, whilst in Fig. 33 they were either parallel or at right angles to it.

Fig. 42 is a portion of the ground plan, to show the angles at which the object is placed in relation to the picture-plane.

The height of the spectator and the distance in Fig. 43 are the same as in Fig. 33.

Having drawn the picture-line and the horizontal line, place

At its lower extremity, S (not shown in Fig. 43), draw a line parallel to the picture-line; and on it, on each side of S, construct angles similar to the angles B A b and C' A c in Fig. 42; produce the lines forming the angles until they cut the horizontal line. The vanishing-points 1 and 2 (not shown for want of space) will thus be obtained, and from these, with the length extending from the vanishing-points to the station-points, the measuring-points may be marked on the horizontal line.

These preliminaries being settled, place the point A′ at the required distance on the left or right of the line of direction, and from it draw lines to the vanishing-points.

On each side of A′ mark off A′ B and A′ C′, and from B and C′ draw lines to the *measuring*-points, cutting the lines A′ V, A′ V in *b* and *c*.

From *b* and *c* draw lines to the vanishing-points, cutting each other in D.

Then A′ *b* D *c* will be the boundary of the plan.

On each side of A′ set off I and J equal to the true width of the piers, and set off the same width K and L on the inner side of B and C′. From I, J, K, and L draw lines to the measuring-point as far as the boundary of the plan, and thence continue them to the vanishing-points. These, crossing, will give the ground-plan of the piers.

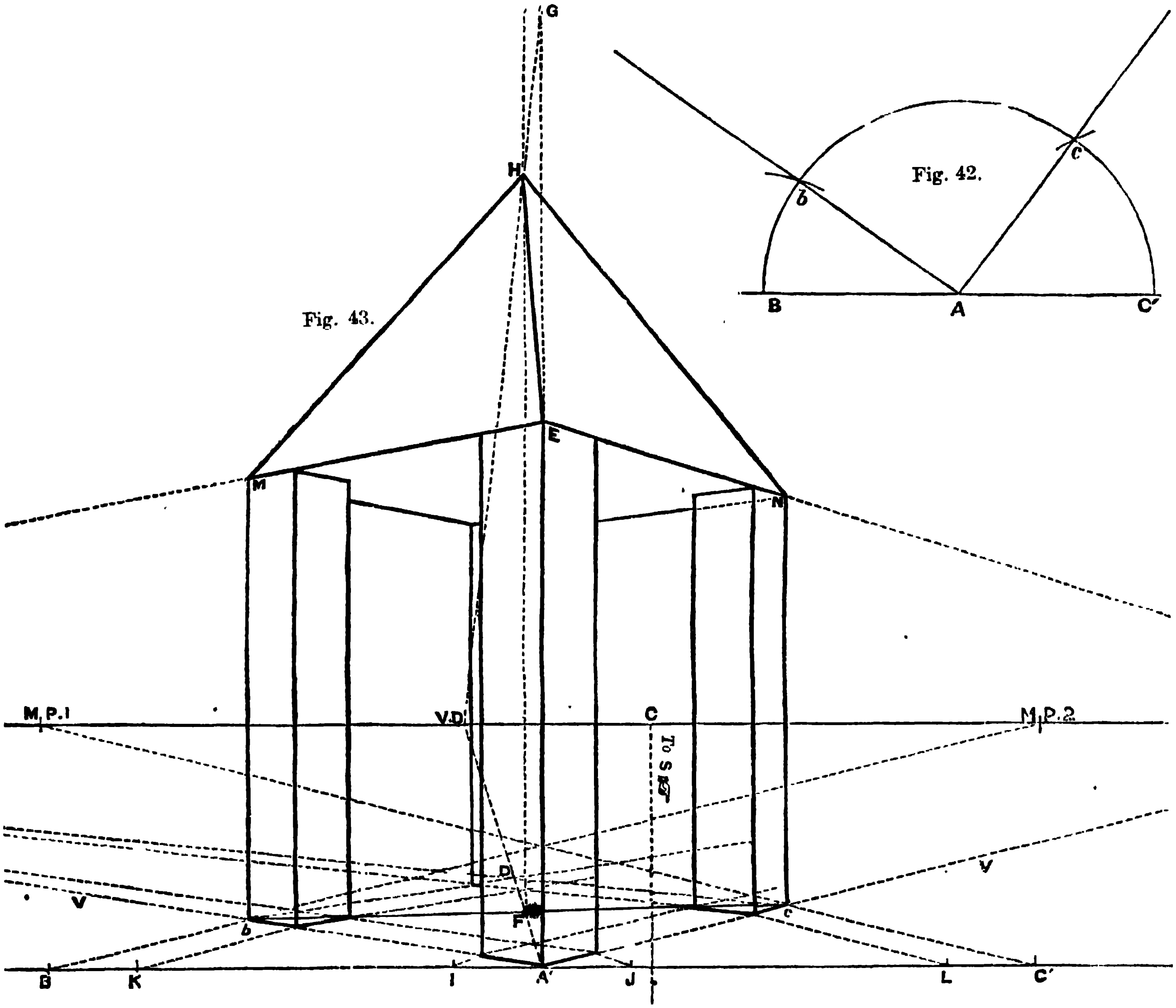


Fig. 42.

Fig. 43.

Before the figure has become too intricate, draw diagonals in it, and produce the diagonal A′ D until it meets the horizontal line in V D, the vanishing-point for the diagonal, the use of which will be presently seen.

At A′ erect a perpendicular equal to the full height of the piers, and from its extremity, E, draw lines to the vanishing-points.

From *b* and *c* erect perpendiculars, cutting the lines last mentioned in M and N, and from these points draw lines to the opposite vanishing-points; these will complete the perspective view of the under side of the pyramid. The perpendiculars completing the piers are to be drawn from the respective points in the plan, as shown in several previous studies.

Produce the perpendicular A′ E until it reaches G, the distance E G representing the real height of the pyramid.

Now from F, the intersection of the diagonals in the plan, erect a perpendicular, and from G draw a line to the vanishing-point for the diagonal, cutting the perpendicular F in H; then H is the perspective height of the pyramid. Draw E H, M H, and N H, which will complete the projection.

EXERCISE 31.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 14 feet.

There is a structure, consisting of—

1. Four piers, 1 foot square at base, and 12 feet high, forming angle piers of a plan 8 feet square.
2. A slab 8 feet square and 1 foot high, resting on the piers.
3. A pyramid 8 feet square at its base and 5 feet high, resting on the square slab.

The edges of the pyramid and slab are parallel to the sides of the square forming the plan.

Put this object into perspective when its sides are at 35° and 55° to the picture-plane, the nearest angle being on the picture-line, at 6 feet on the right of the spectator.

EXERCISE 32.

The scale, height of spectator, and distance the same as in the last exercise.

Put into perspective the same object when placed at 5 feet on the right of the spectator, and when standing on a block of stone 8 feet square at base and 1 foot high.

WEAPONS OF WAR.—IX.

BY AN OFFICER OF THE ROYAL ARTILLERY.

RIFLED GUNS.

THE increasing and over-active tendency to multiply the destructive effects of fire-arms, by increasing their range and precision, and by supplying them with projectiles more and more deadly and irresistible, naturally operated to recommend the conversion of the smooth-bore gun into the rifled gun, just as it had caused the supersession of Brown Bess by the Enfield rifle. Indeed, it may be said that the introduction of rifled small arms rendered it not a matter of choice but a matter of necessity for the artilleryman to develop the weapons of his craft in the same way, and, as far as possible, in the same degree. If artillery was to hold its place at all, it must meet the Enfield and the Minié rifles with a field-piece as superior to those weapons as the old smooth-bore 9-pounder was superior to Brown Bess; and the device by which the infantry soldier's weapon had been rendered so much more powerful was naturally resorted to by the artillerist, to increase proportionally the power of his own particular arm. We had got the rifled musket; it was therefore necessary for us to have the rifled gun. We trust we shall not be misunderstood as wishing to affirm that the rifled gun was first proposed after the introduction of the Enfield rifle, and in consequence of it. Such a statement would be promptly and properly contradicted by antiquarians, who would point to occasional examples of very ancient rifled guns; and by experimentalists, who would remind us of Mr. Joseph Manton's rifled 6-pounder of 1790, of Lieutenant-Colonel Dundas's rifled gun of 1836, of the Cavalli gun of 1846, of the Wahrendorf gun of 1847, of Captain Norton's experiments with rifled cannon, and many others. But the introduction of rifled small arms certainly gave an impetus and earnestness to the exertions to introduce a rifled cannon which had before been wanting, and experiments which had up to that time possessed only a sort of speculative and uncertain interest now became invested with a new power, which drew towards them the attention of the military world.

Before proceeding to enumerate some of the more remarkable devices for communicating a rifled motion to the projectiles of cannon, it may be well to say a few words as to the object of rifling a gun. What is rifling intended to accomplish? What do we gain by it? To this the first answer will perhaps be, We gain the power of firing an elongated instead of a spherical projectile. But this answer would be in part incorrect. It is true, but it is not the whole truth: for we may remind our readers that the first rifled small arm in use in the British service was, as stated in a former paper (Vol. I., page 65), the Brunswick rifle; and the Brunswick rifle threw not an elongated but a spherical belted ball. The first object of rifling a gun or small arm, then, is to obtain rotation on a fixed axis. This object is equally aimed at whether the projectile to be fired be spherical or elongated. In the case of the spherical ball, the rotation upon a fixed axis gives increased accuracy, by eliminating in great measure the errors due to the eccentricity and irregularity of the projectile. Projectiles cannot in practice be made absolutely and uniformly true as to concentricity, weight, and form, and any departure from absolute truth in these points is attended in a ball fired from a smooth-bore piece with a corresponding loss of accuracy. But if a fixed rotatory movement be communicated to that ball, the uncertain rotation due to the position of the centre of gravity will disappear, and with it one source of error; while the inaccuracy due to any irregularities of form and surface will be greatly diminished in consequence of the pressure of the air being more equally distributed around the projectile, the position of which in reference to this air is constantly changing. So that when a spherical ball is fired from a rifled piece we get at once greater accuracy, and this is an advantage which belongs to rifling, whether elongated projectiles be employed or not. But rifling is more valuable as rendering possible the use of elongated projectiles, with all the advantages which flow from their employment. Why cannot elongated projectiles be fired from smooth-bored guns? Because of the pressure of the air acting upon them unequally, and causing them to turn over in flight. "If the centre of gravity of the projectiles be very far forward, it is possible," says Lieutenant-Colonel Owen, in his admirable "Modern Artillery," "to fire them from smooth-bore guns at short ranges." But this is the only case in which an elongated projectile could be fired without rotation; unless, indeed, we could suppose a shot fired in a vacuum, in which case, as there would be no air to press upon it, it would not turn over. If rapid rotation be established upon the longer axis of the projectile, the velocity of rotation will more than counterbalance the pressure of the air, and will prevent the projectile from being turned over. Any one who has amused himself with the gyroscope, or even a child who has played with a top, will know that the spinning motion gives a stability to the axis of rotation which, as long as the spin is strong enough, sets other disturbing forces at defiance. Thus a top or a gyroscope will spin at an angle with the horizon which it could not possibly maintain if it were not in motion. Indeed, a top could not stand at all without being spun, and the wobbling movement which precedes its fall indicates the point at which the force of gravity is beginning to re-assert its sway, and to overcome the failing rotation. These are elementary truths, but they perhaps explain better than more recondite examples the effect of rifling upon a projectile.

Well, then, having advanced thus far—having established that rifling neutralises some of the causes of inaccuracy in the projectile, whether spherical or elongated, and that without it it would not really be practicable to fire an elongated projectile at all—we have to inquire further, what are the advantages of firing elongated projectiles? Those advantages are as follow:—In the first place, weight for weight, the elongated projectile presents a diminished surface for the resisting medium—whether air, or iron, or wood, or water—to act upon. Weight for weight, therefore, the elongated projectile will range and penetrate farther than the spherical projectile of the same material. Or, weight for weight, equal results may be obtained with the elongated projectile with a reduced charge of powder. If the surface of the elongated projectile be increased to that of the sphere with which it is compared, its weight will be greater, and thus it will have greater powers of overcoming an equal resistance. Fourthly, it is often a great advantage to make the striking part of a projectile of a peculiar form and of a peculiar material. The shape of the head will greatly affect the flight; the shape and material of the head will greatly affect the penetrative power. The Palliser projectile of chilled iron would not be possible with an obtuse or hemispherical form of head. It is necessary, as will hereafter be more fully explained, to have a head of a form suitable for neutralising the brittleness of the material, and this is possible with an elongated shot which goes point foremost—it would not be possible with a sphere. Again, the heads of the present Palliser shot are made harder than the bodies, as the gouge or chisel is made harder than its handle. This would not be possible with the sphere. Every projectile in the service has a head of a form which is considered suitable for flight—for cleaving its way with the minimum of resistance and disturbing effect through the air, just as ships are made with bows suitable for easy passage through water. Such an arrangement would not be possible with a sphere. Fifthly, as an elongated projectile meets, in relation to its weight, with less resistance from the air than a spherical projectile, the trajectory of the former will, *cæteris paribus*, be flatter. Sixthly, all elongated projectiles for the same gun can be made of the same *weight*, if desired, so as to be fired with the same charge of powder and the same elevation. With the sphere, all the projectiles for the same gun must be made of the same *size*; and thus the common shell, which is filled with powder, will weigh considerably less than the shrapnel, which is filled with leaden bullets, and will require a different elevation. Seventhly, if a specially long or powerful projectile be required—as, for example, a "double shell"—this requirement can be satisfied with elongated projectiles, it cannot be satisfied with spheres. Eighthly, the fact of a projectile travelling head foremost greatly facilitates the preparation of a suitable percussion fuse, as it is only necessary to provide for action in one direction. This advantage would, it is true, be possessed by the *rifled* sphere, and is therefore rather an advantage of rifling abstractedly than of that particular application of rifling which gives us the elongated projectile. The same may be said of the advantage which rifling gives in respect of shells which are required to act or open to the front in any particular way. Thus, the Palliser shell is required to strike point foremost; the Boxer rifled shrapnel is required to deliver its bullet to the front.

The advantages of rifling may therefore be summed up, as pointed out by Captain Orde Browne, R.A., in his "Treatise on Ammunition for Rifled Ordnance," as follow :—

1st. Accuracy.

2nd. Simpler action of percussion or concussion fuses.

3rd. Distribution of the metal with a view to the special requirements of each projectile.

The above advantages apply whether the rifled projectiles be spherical or elongated.

Then, from the use of elongated projectiles, which rifling renders possible, we get,

4th. Power of making the head of any form required.

5th. Greater range or penetration.

6th. Saving of powder.

7th. Flatter trajectory.

8th. All projectiles for the same gun may be brought to the same weight.

9th. If required, a specially heavy projectile may be given to any gun, for exceptional use.

These are the advantages which we realise from rifling our guns. Let us now pass on to observe in what way this rifling has been proposed to be accomplished.

To most persons the idea of rifling almost necessarily suggests a gun with grooves cut in it, and shot furnished with studs or other projections to fit those grooves. But although this may be the simplest and most natural way of rifling a gun, it is very far from being the only way. The Whitworth gun, for example, has no grooves, properly so called, and no projections upon the shot. It is, roughly speaking, a spirally hexagonal bore, which fires a spirally hexagonal shot. The Lancaster gun had an oval bore, and fired an oval shot. Then there have been numerous propositions for reversing the ordinary method of rifling, and making the grooves in the shot, with corresponding projections in the gun. But it is not necessary that the gun should be rifled at all. The Mackay gun is a smooth-bore, which fires a grooved projectile, the rush of gas along these grooves being supposed to communicate a rotatory motion to the projectile. Many proposals have been made for communicating rotation by the pressure of the air upon the projectile after it has left the bore, by acting on oblique planes or channels, either in front or in rear of the shot. The Museum of Artillery at Woolwich contains many specimens of each of these different modes of rifling. Looking at them broadly, we shall find that they may be classified, as pointed out by Lieutenant-Colonel Owen, under three heads :—

1. Mechanical means inside the bore of the gun.
2. The action of the powder-gas upon the shot inside the bore.
3. The action of the air upon the projectile after it has left the bore.

The common object which all proposers of systems of rifling have had in view, is the spinning of the projectile on its longer axis, and with that axis as nearly as possible coincident with the axis of the bore or its prolongation. It is important to do this in a manner the least injurious to the guns, which will permit of easy loading, and which will impose no serious mechanical difficulties upon the manufacturers of the guns and projectiles. To discuss the merits and demerits of the various systems of rifling would occupy more space than can now be afforded, and would be beyond the scope of these papers. Indeed, allusion has been made to the various experimental modes of communicating a rotatory motion to projectiles chiefly to warn those who may contemplate the trial of some supposed novelty in rifling that they will do well first to inspect the valuable collection of rifled projectiles which exists at Woolwich, and to learn from them the proportion of failures to successes.

The system of rifling of which it is first necessary to make mention at this stage of the subject is that employed by Sir William Armstrong in his original guns. The Armstrong shot were coated with a leaden coating, slightly larger than the bore, and which on the explosion of the charge became forced into the numerous shallow spiral grooves with which the guns were provided, and which thus spun the projectile. The advantages of this system, the *système forcée* (as the French call it), are that it gets rid of windage, that it ensures complete centring of the projectile, and that it gives great accuracy. *Per contra*, the system is one which entails the use of lubricators, it imposes a great strain upon the gun, it is very costly, on account of the price of the lead-coating, and the lead-covered projectiles are very liable to get disfigured in transport. Moreover, when lead-coated projectiles are fired against armour-plated ships, the lead coating, although it has increased the momentum of the shot, acts as a bar to its free progress through the plate, and thus lessens its power of penetration. The difficulties which were at first experienced in connection with the firm attachment of the lead-coating have been overcome by the adoption of the plan proposed by Mr. Bashley-Britten, of soldering on the lead with zinc solder, instead of attaching it mechanically. All the breech-loading guns in the English service fire lead-coated Armstrong projectiles.

The muzzle-loading guns fire studded shot, and are rifled with three or more grooves, according to their size. An ingenious system of grooving, known as the "shunt" system, which was designed by Sir William Armstrong, is fast dying out, and hardly calls for notice. It is merely necessary to observe that with this system the shot loaded easily on the deep side of the groove, and in coming out hugged the opposite or "driving" side, being "shunted" in its passage up the bore on to a shallower level. The objection to this system was that it was apt to strip the studs off the projectile, by throwing on to them a sudden strain at the moment when the shot took the shallower level. In some instances it is considered the strain acted injuriously upon the gun.

The "Woolwich" guns—by which is meant all our heavier muzzle-loading rifled guns—have a groove very nearly akin to that used in the French guns. In some cases the spiral is made uniform throughout the bore; in the majority of cases it is quicker at the muzzle than at the breech. The supposed advantage of the increasing twist is that it slightly diminishes the strain upon the gun. The projectile meets with little or no resistance from the grooves at the instant when it is propelled forward by the ignition of the charge, and it is only as the projectile travels forward in the bore that the resistance due to rifling becomes sensible. But this resistance is far less than is commonly supposed, and it is doubtful if the increasing spiral really affords anything like that amount of relief to the guns which was at one time believed. It is considered that the increasing spiral gives also greater accuracy of fire.

In the field guns the form of groove is rather different from that of the Woolwich guns, and the play between the studs and grooves is less. But these are details with which it is not necessary to encumber the present papers. It will be sufficient to observe that there are two main systems of rifling in vogue in the British service—namely, the system of many shallow grooves, with lead-coated projectiles, for the breech-loading guns: and the system of few deep grooves, with studded projectiles, for the muzzle-loading guns. The *rationale* of rifling has also been explained, and the advantages which it gives us have been set forth. We will in our next paper pass on to the construction of our rifled guns, and show the principles upon which they are built.

PRINCIPLES OF DESIGN.—XIV.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

DECORATION OF CEILINGS (*continued*).

In my last article I noticed that the decoration of a room should be in character with its architecture, but that while this should be so, the ornament applied by way of enrichment should not be a servile copy of the decorative forms employed in ages gone by, but should be such as is new in character, while yet of the spirit of the past.

Many circumstances tend to determine the nature of the decoration which should be applied to a ceiling: thus, if a ceiling is structurally divided into square panels, the character of the ornament is thereby restricted, and should these panels be large, it will probably be desirable that each be fitted with the same ornament; while if they are small three or four different patterns may be employed, if arranged in some orderly or methodical manner.

A ceiling may also have the joists or beams visible upon it: in this case the decoration would have to be of a very special character. The bottoms of the joists might have a string pattern upon them (a running pattern), as the Greek "key," or guilloche; whilst the sides might have either a running pattern, or a pattern with an upward tendency, as the "Greek honeysuckle;" and the ceiling intervening between the joists might have a running pattern, or better, a star, or diaper pattern, or it might have bands running in the opposite direction to the joists, so as, with them, to form squares, which squares might be filled with ornament.

If, however, the ceiling is flat, and is not divided into sections structurally, almost any "setting out" of the surface may be employed, as Fig. 40; or a large centre ornament, as Fig. 41; or a rosette distributed over the entire surface, as Fig. 42. In any case it is not necessary or even desirable that the ornament be in relief upon the ceiling. Flatly treated ornaments may be employed with advantage, and all fictitious appearance of relief must be avoided.

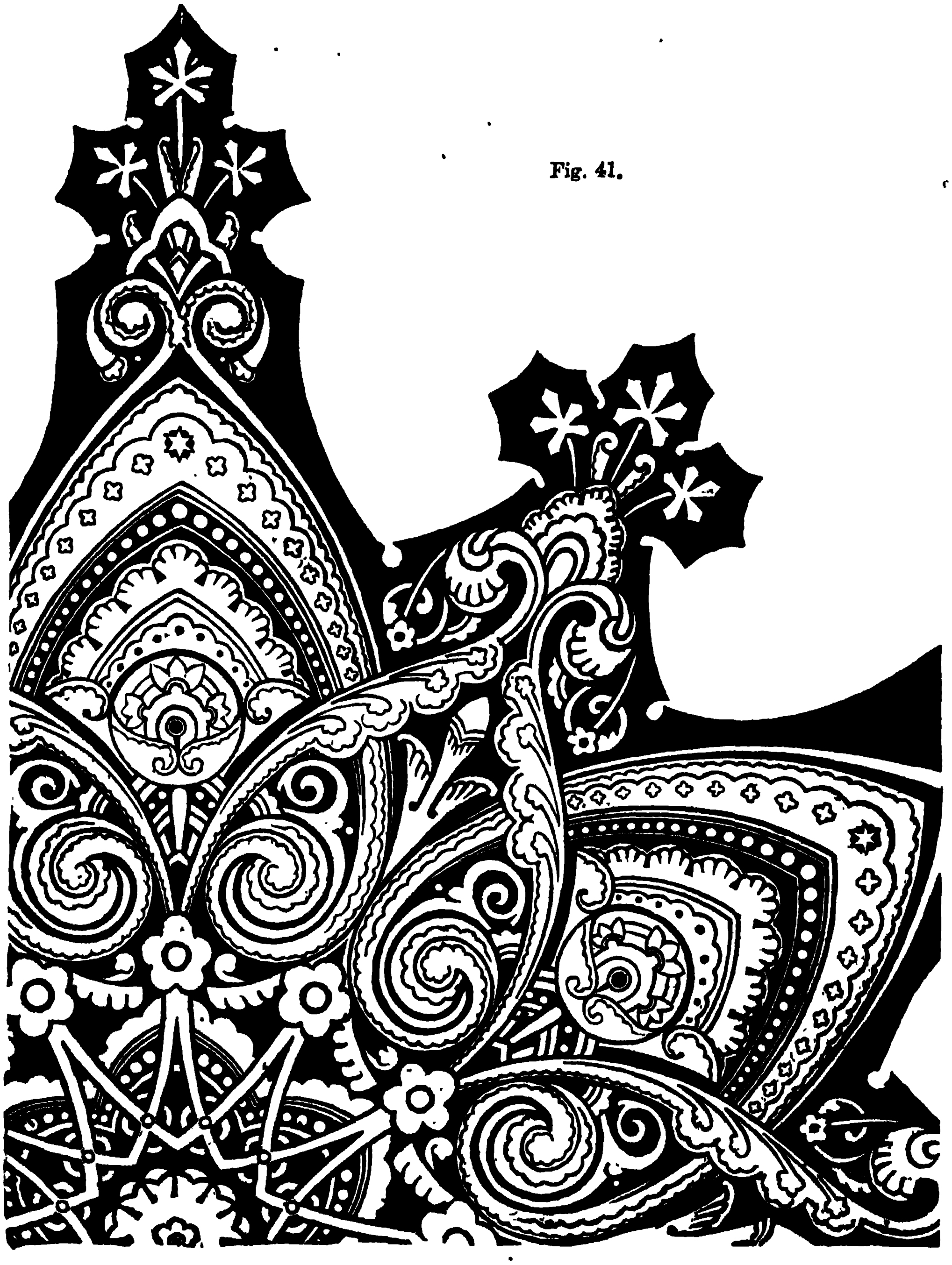


Fig. 41.

There are so many different ways of setting out ceilings, that I cannot attempt even to make any suggestions. I would simply say, however—Avoid an architectural setting out, if there are no structural members; for ornament which is fla may spread in any manner over a surface without even appearing to need structural supports. As to the colour of a ceiling, if there is to be no ornament upon it, let it be a cream colour (formed of white with a little middle chrome) rather than white. Cream-colour always looks well upon a ceiling, and gives the idea of purity. A grey-blue is also a very desirable colour for a ceiling, such as is formed of pale ultramarine, white, and a little raw umber, just sufficient to make the blue slightly grey (or atmospheric). In depth this blue should be about half-way between the ultramarine and white. Another effect which I like is produced by the full colour of pure (or almost pure) ultramarine. In this case the cornice should be carefully coloured, and pale blue and white should prevail in it.

A further and very desirable effect is produced by placing pale cream-coloured stars irregularly over the pale blue, or even the deep blue ceiling, or by placing pale blue stars upon the cream-coloured ceiling. The stars should vary for an ordinary room ceiling (say a room sixteen feet square by ten feet high) from about three inches from point to point down to one inch; the larger stars having six points; others being smaller and with five points; and the small ones having, some four points, and some three. If such stars are irregularly (without order) intermixed over the ceiling, and yet are somewhat equally dispersed, a very pleasing and interesting effect will thereby be produced. This effect is in much favour with the Japanese.

Another good effect is produced by giving the ceiling the colour of Bath or Portland stone, and starring it with a deeper tint of the same colour. This effect is improved by each star having a very fine outline of a yet darker tint of the same colour.

I should recommend those interested in the decoration of ceilings to study carefully the Egyptian, Alhambra, and Greek Courts at the Crystal Palace, Sydenham, especially the two last named; also to notice the ceiling in St. James's Great Hall, Piccadilly, London, and the ceiling of Ushaw College chapels near Durham. The ceilings in the Oriental Courts, by Mr. Owen Jones, at the South Kensington Museum are worthy of careful notice; but the Renaissance ceilings in other parts of the Museum are both wrong in principle and bad examples of their style. The structurally formed glass ceiling of the Crystal Palace Bazaar in Oxford Street, London, and still better, the ceiling of Mr. Osler's glass warehouse in Oxford Street, are well worthy of note.

On the Continent we very frequently meet with ceilings on which large pictures have been painted, as in the Louvre and the Luxembourg in Paris; and the authorities of the South Kensington Museum are making efforts to introduce this style into England, but such pictorial ceilings are in every way wrong.

1st. A ceiling is a flat surface, hence all decoration placed upon it should be flat also.

2nd. A picture can only be correctly seen from one point, whereas the decoration of a ceiling should be of such a character that it can be properly seen from any part of the room.

3rd. Pictures have almost invariably a right and wrong way upwards. A picture placed on a ceiling is thus wrong way upwards to almost all the guests in the room.

4th. In order to the proper understanding of a picture you must see the entire of its surface at one time; this is very difficult to do without almost breaking your neck, or being on your back on the floor; whereas, an ornament which consists of repeated parts may render a ceiling beautiful without requiring that the whole ceiling be seen at the one glance.

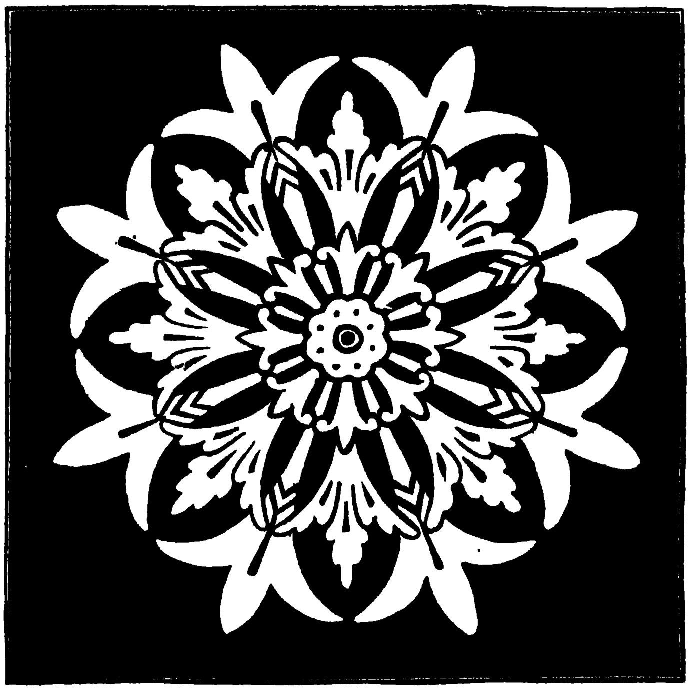


Fig. 42.

Most of the French pictorial ceilings are so painted that they are properly seen when the spectator stands with his back close to the fire. This is very awkward, as the rules of society do not allow us to stand in this position before company. Pictorial works are altogether out of place on a ceiling; they ought to be framed and hung right way upwards upon walls where they can be seen. We have a painted ceiling at the Greenwich Hospital.

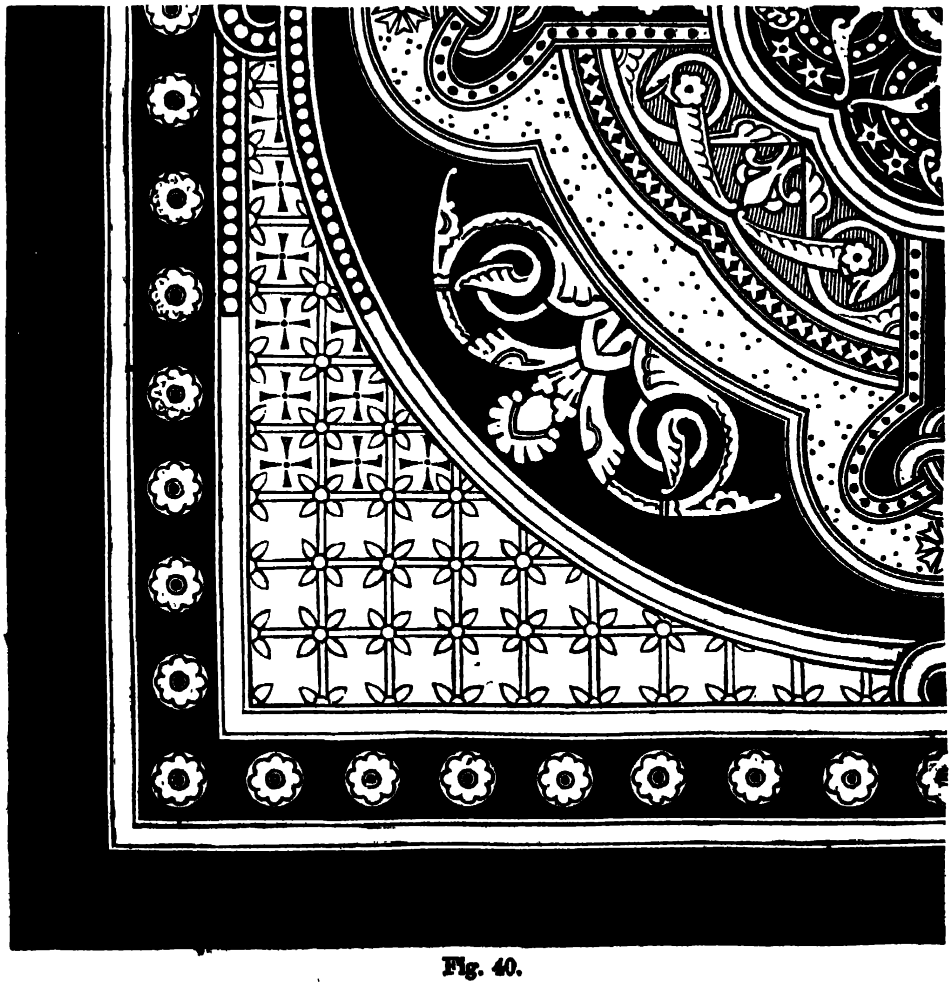


Fig. 40.

Arabesque ceilings, such as that of the Roman Court at the Crystal Palace, are also very objectionable.

What can be worse than festoons of leafage, like so many sausages, painted upon a ceiling, with griffins, small framed pictures, impossible flowers, and feeble ornament, all with fictitious light and shade? But not content with such absurdities and incongruities, the festoons often hang upwards on vaulted or domed ceilings, rather than downwards. Such ornaments arose when Rome, intoxicated with its conquests, yielded itself up to luxury and vice rather than to a consideration of beauty and truth.

Decorations like these were to an extent again revived by the great painter Raphael; but it must ever be remembered that Raphael, while one of the greatest of painters, was no ornamentist. It requires all the energy of a life to become a great painter; and it requires all the energy of a life to become a great ornamentist; hence it is not expected that the one man should be great at the two arts.

In all ages when decorative art has flourished, ceilings have been decorated. The Egyptians decorated their ceilings, so did the Greeks, the Byzantines, the Moors, and the people of our Middle Ages, and a light ceiling appears not to have been esteemed as essential, or as in many cases desirable. It is strange that so few of our houses and public buildings contain rooms with decorated ceilings; but the want is already felt, the fashion has set in, and many are at this present moment being prepared. We must get simple modes of enrichment for general rooms—modes of treatment which shall be effective, and yet not expressive—and then we may hope that they will become general.

The large centre ornament for ceilings shown in Fig. 41 is necessarily given in portions, but students of decorative art are recommended to copy and complete these drawings in their entirety, as useful studies of symmetrical design, and for practical purposes to draw them on a large scale on cartridge paper, and colour them according to the rules already laid down, that they may be able to judge fairly of the general effects produced.

APPLIED MECHANICS.—XII.

BY ROBERT STAWELL BALL, M.A.,

Professor of Applied Mathematics and Mechanism, Royal College of Science, Ireland.

THE PLANING MACHINE.

In the last lesson we introduced the important principle of the slide-rest as applied to the turning lathe; in the present lesson we shall consider the no less important application of the slide-rest to the planing machine. The lathe affords the means of obtaining surfaces of revolution, the planing machine enables us to produce planes with wonderful precision. When we consider that nearly all the acting surfaces of machines are either planes or surfaces of revolution, the importance of the slide-rest in producing such surfaces becomes manifest.

In the planing machine the work is moved while the tool remains at rest, thus differing from shaping and slotting machines, in which the work remains at rest while the tool is moved.

The planing machine consists of a table which is adapted to slide on two grooves, so that all parts of the table move in parallel lines. On this table the work is placed, and secured in the proper position by screws. The work thus traverses backwards and forwards with the table: attached to a frame above the table is the slide-rest, which carries the tool. The point of the tool traces out a straight line upon the work which moves beneath it, and if, therefore, at the conclusion of each cut the point of the tool be advanced in a straight line, so as to take a fresh cut, a plane surface will be produced upon the work.

There are many ingenious mechanical contrivances in the planing machine, both for producing the return motion of the work, and also for making the tool self-acting. These we shall describe.

We take the following very interesting passage from Mr. Nasmyth's remarks upon the use of the slide-rest (see "Baker's Mechanism," p. 227):—"There is no form which is so frequently required and essential to any piece of mechanism as the plane surface, or rectangular prismatic forms generally. The vast expense attendant upon the production of such by the tedious and unsatisfactory process of chipping and filing caused every engineer to avoid by all means any arrangements which rendered such forms necessary, however essential they might be to the perfect action of the machine. It is quite laughable to observe in any old piece of mechanism the niggardly use of those important forms, arising from the above obstacle. The introduction of the planing machine at once altered the entire system, inasmuch as forms and arrangements became practically possible which formerly the engineer dared not think of using; this was simply following out in the plane surface what the slide-rest had produced in the turning-lathe as regards cylindrical forms. And the result was that not only was the machinery produced by its agency most strikingly superior by its direct influence, but also that the planing machine enabled us to produce improved tools at a greatly reduced cost. That mighty influence in all affairs, the first planing machine, enabled us to produce the second still better; that again produced a better still; and then slide-rests of the most perfect kind came streaming forth from them, and they again assisted in making better still; so that in a short time a very important branch of engineering—namely, tool-making—arose, which had its existence, not merely owing to the pre-existing demand for such improved tools, but, in fact, raised as it were upon a demand of its own creating, and all this caused by the slide-rest and its offspring, the planing machine. One has only to go into any of those vast establishments which within the last thirty years have sprung up for the purpose of supplying the demand for machinery, and we shall find that nine-tenths of all the fine mechanisms in use and in process of production is through the agency, more or less direct, of the slide-rest and planing machine."

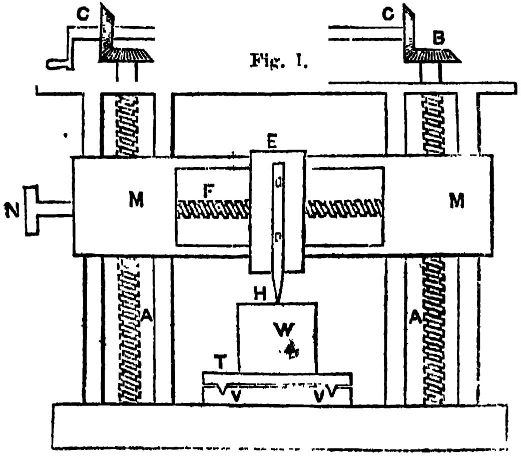


Fig. 1.

We shall first describe the mechanism by which the motion of the tool secured in the slide-rest can be obtained. A diagrammatic view of a planing machine is given in Fig. 1. T is the table sliding on V grooves (we shall consider its motion presently); W is the work upon which a plane surface is to be produced. The table is furnished with a number of slots, and the work is secured to the table by means of bolts of various forms, the heads of which are underneath the table, while the shanks pass through the slots; brackets and other ingenious contrivances are used for securing work of different forms. The reciprocating movement of the table is thus partaken of by the work, and as the table moves the work, the point of the tool, H, takes off a shaving. The tool is attached to a slide, E; on E is a nut in which the screw F works: the frame M M is horizontal: consequently, when the screw F is made to rotate by the handle N, the point of the tool is moved in a horizontal line perpendicular to the direction of motion of the table. After each cut has been taken the tool is moved a little, and then on the return of the table a fresh cut is taken. Thus the movement of the table, compounded with the movement of the tool, develops a plane surface upon the work. In order to economise labour, and still more to secure regularity and perfect uniformity in the work, the tool is not generally moved by the hand of the workman. The wheel N is fastened on the screw, and, by means of a simple contrivance, the table itself, after the conclusion of each cut, and before the commencement of the next, turns the wheel a little, thus making the machine self-acting.

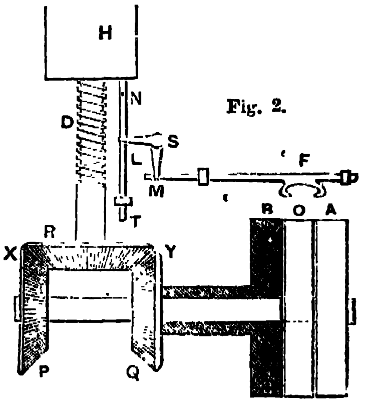


Fig. 2.

In order to accommodate the tool to the varying dimensions of the work which the planing machine may receive, the frame, M M, is itself able to receive a vertical motion. The vertical screws, A, A, work into nuts on the back of the frame, M M; these screws have small bevelled wheels, B, B, keyed upon them; these bevel wheels are equal, and are turned by the two equal bevelled wheels, C, C. Thus, by turning the handle D, the whole frame, M M, can be raised or lowered at the commencement of the work, in order to place the tool at the required height. It will, of course, be understood that during the process of planing the position of the frame M M must not be altered.

We have now to describe the mechanism by which the table is moved. The problem we have to solve is more complicated than the simple motion of revolution which has to be produced in the lathe. The table has to be moved backwards and forwards, and the extent of its motion must, in order to save time, be accommodated to the length of cut. In some planing machines the support which carries the tool is capable of being turned round, so that on the return of the table a cut may be taken as well as in the forward motion. Other machines have not this contrivance: but the table is brought back by a more rapid movement than it would be possible to use for planing: thus the loss of time on the return is reduced to a minimum.

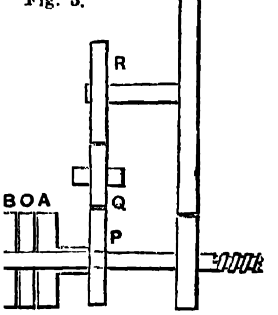
In Fig. 2 is a diagram of a planing machine in which the tool is intended to be turned round, so that both motions are performed with equal velocities.

The table is moved by a screw which revolves beneath, and works into a nut attached to the table. This screw is shown at D; H is the table. We have only shown in this figure the portions which relate to the motion of the table. The screw is attached to a bevelled wheel, R; this wheel, R, may be turned by either of the wheels, Q and P, into which it gears. The wheel Q is attached to the pulley B; Q and B turn together quite freely upon the shaft. When the band which drives the planing machine is upon B, the wheel Q is turned, and this makes the screw revolve. Of course R will turn round P in the opposite direction to that in which Q rotates. But now let the band be shifted from the pulley B to the pulley A. A will now be driven round, and with it P, because P and A are both keyed upon the same shaft, which passes freely through B and Q; hence the bevelled wheel R, and therefore the screw, will now be driven by the wheel P. It will be easy to see that R will move in opposite directions, according as it is turned by P moving in one direction or Q moving in the same direction. Suppose, for example, that the wheel P turn so that the part of it near X descends, then the part of R at Y ascends, whereas had the motion been given by Q, the part Y descends, of course making the part near Y on R descend; hence we have a most convenient means of reversing the table by just shifting the band from one pulley to another; between the pulleys A, B is a third pulley, O. This is what is called an idle pulley, because it turns freely on the shaft. The band is therefore turned on this pulley when it is desired to throw the machine out of action.

We have now to describe that very ingenious portion of the mechanism whereby, when the table has arrived at the end of its stroke, it changes the band from B to A, and thus itself reverses the motion. Underneath the table is a rod, N L T. One of the guides which restrain this rod to a motion parallel to the table is shown at T. A stud upon the rod is shown at N; this stud can be attached by a screw to any point of the rod. The table in advancing towards R comes in contact with N, and thus pushes the rod N L T forwards. A pin upon the rod at L works in a slot in a bell-crank lever, M S L. We have already described the bell crank lever in our lesson upon the lever; it gives a convenient method for changing motion from one line to another line perpendicular to it. When L is pushed on, it is evident that M will act on the rod M P; but M P carries a fork O, through which the band passes; thus the band will be carried from the wheel B to the wheel A. The table will then commence to move in the opposite direction until it meets a second stud on the rod T L N, which serves to bring the band back again to B. Thus the table will reciprocate without the attention of the workman. The position of the studs upon the rod N T is to be determined by the length of cut which is required. The reversal of the tool at the conclusion of the cut before the table commences to return can also be effected by a self-acting apparatus.

In the best planing machines, which are used when very superior work is required, a quick return motion is considered preferable to the rotation of the tool, notwithstanding the sacrifice of time that is involved. Various ingenious mechanical contrivances are made use of for the rapid return motion. One of the most useful of these is shown in Fig. 3.

Fig. 3.



O is an idle wheel, and A and B are the pulleys which move the table. When the band is on B the motion of the screw is slow in one direction, but when the band is on A the screw revolves rapidly in the other direction. The arrangement for shifting the band is the same as that we have already described; so this diagram merely shows how the difference between the velocities of advance and return is obtained.

The pulley A is attached to the toothed wheel P; so that when A is turned, P must turn with it; these wheels turn freely upon the shaft. Q and R are also toothed wheels. We shall suppose that P and R are of the same magnitude, the size of Q being indifferent. P and Q revolve in opposite directions, so do Q and R; therefore P and R revolve in the same directions, and, since they are equal, with equal velocities. T is a large toothed wheel on the same shaft as R. We shall suppose, for the sake of illustration, that T has sixty teeth. T revolves, therefore, in the same direction as P, and they each perform one revolution in the same time. T gears into a wheel, S; this wheel is upon the screw which moves the table. If S have twenty teeth, it will turn round three times for each revolution of T, and, of course, in the opposite direction. Hence S turns round in the opposite direction to the motion of P, and revolves three times when P has turned round once; this corresponds to the return motion of the table. But when the band is shifted from A to B by the fork, the motion is reversed. The shaft on which B is keyed is a continuation of the screw S, and hence the screw revolves in the same direction as the motion of B, and with the same velocity. Thus the table is brought back three times as fast as it is advanced.

VEGETABLE COMMERCIAL PRODUCTS.

XX.

MISCELLANEOUS PLANTS OF COMMERCIAL VALUE (*continued*).

COQUILLA NUT (*Attalea funifera*; natural order, *Palmaceæ*).—This is the fruit of a South and Central American palm. It is a nut of not more than three inches in length and two in breadth, and is completely solid, excepting a small cavity in the centre, in which the seed is deposited. The shell is therefore very thick, and it is also very hard, taking a fine polish. Coquilla nuts are used chiefly by ornamental turners for the production of small knob handles for cabinet drawers, parasol and umbrella handles, chessmen, rings, brooches, and small toys. About 300,000 nuts were imported in 1852.

MARKING NUT (*Semecarpus anacardium*; natural order, *Anacardiaceæ*).—A native of the East Indies. This nut, somewhat like a tamarind stone, has an exterior covering formed of two laminæ, between which is a caustic bitter juice staining an indelible black, and which is much used as a black varnish, as well as for marking linen, whence its name, "marking nut." It is imported into this country for these purposes.

ORRIS ROOT (*Iris Florentina*; natural order, *Iridaceæ*).—This plant is a native of Italy, and cultivated in gardens. Orris root is used as an ingredient in tooth powders, and in the perfumed preparation of wheat starch called violet powder. About five tons are annually imported.

CRABS' EYES (*Abrus precatorius*; natural order, *Leguminosæ*).—This is a pretty climbing plant, a native of the West Indies. Its seeds are bright scarlet, jet black round the hilum, and very handsome. In India they are used by druggists and jewellers as weights, being almost uniformly one grain. They are also strung together for necklaces and rosaries.

RATTANS (species of *Calamus*; natural order, *Palmaceæ*).—These palms yield the canes or rattans of commerce. They have very long slender stems, with leaves at considerable distances apart, and the climbing species reach the tops of the highest trees by means of the powerful whip-like prolongations from the midribs of the leaves. The stems contain a considerable amount of silex, which renders them hard and gives them a glossy appearance. *C. rudentum* produces stems 300 feet in length, which make excellent ropes of immense strength, and as such are used by the native Hindoos in catching elephants. *C. Scipionum* furnishes the walking-sticks known as Malacca canes. *C. rotang*, *C. rudentum*, *C. verus*, *C. viminalis*, and others, are used in this country for the bottoms of chairs and couches, the sides of carriages, etc.; and in India are made into baskets, mats, hats, and other useful articles. They are also used as ropes and cables, in the junks and coasting vessels, and take the place of chains in native suspension bridges.

The rattans are found in commerce in bundles, each cane being once or twice doubled up in order to make the bundle smaller and more compact; the canes are very seldom less than twelve or even sixteen feet in length. About 75,000 bundles of canes, 100 canes being in each bundle, or 7,500,000 canes, are annually imported into the United Kingdom. Holland also imports annually several million pieces. Bengal, Arracan, and the Sunda islands produce the greatest quantity of rattans, and Europe is supplied *viâ* London, Amsterdam, and Rotterdam.

BAMBOO (*Bambusa arundinaceæ*; natural order, *Gramineæ*).—This gigantic tropical grass is extensively spread over India, China, and Japan. It grows like a tree, shooting up with great rapidity in two or three months to a height of fifty or sixty feet. Its hollow stems, which attain a diameter of seven or eight inches, are much used for building purposes in the countries where it grows, and its young shoots serve as walking-canes. The Chinese make from the inner bast-like bark an inferior kind of paper.

TECHNICAL DRAWING.—XXXII.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*)—THE GOVERNORS.

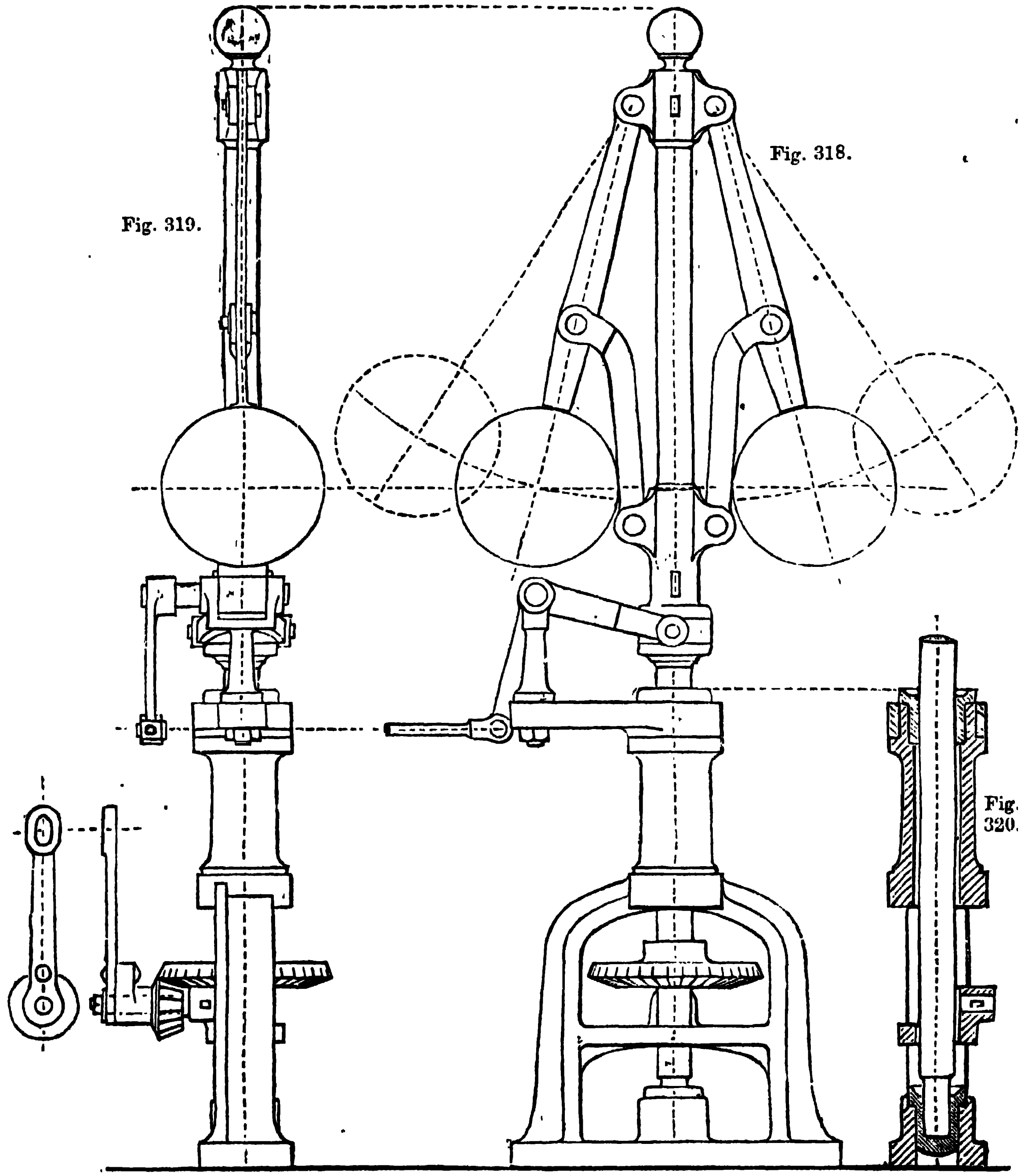


Fig. 319.

Fig. 318.

Fig. 320.

It will be found that this portion of our series of lessons in Technical Drawing supplements in a great measure the lessons on the Steam-engine given in this work. In these the machinist and engineer will find practical working drawings of different parts of the steam-engine, while in the papers to which we have just alluded the student may derive the necessary instruction respecting the different forms of steam-engines, with an accurate description of the purposes which each component part and special feature tends to serve. In the present lesson we shall describe the governors.

The governors are an important part in the details of a steam-engine, and form an excellent study for mechanical drawing. Their use is to regulate the speed of an engine and keep it uniform, and they perform this duty by closing the throttle-valve before mentioned (Figs. 304, etc.), and so shutting off some of the steam. The governors are really a pair of conical pendulums, and when put in rotation the centrifugal force of the balls, or their tendency to fly outwards, increases as they revolve faster. They are suspended by the upper end of the pendulum-rod, and so must rise higher if they fly outwards; at first a very slight elevation accompanies their extension, but afterwards the elevation becomes greater and greater for every further extension. As the action of gravity is constant, and not affected in any way by their revolution, there will be two balanced forces at work: one, the centrifugal power of the balls; and the other, gravity; one variable with the speed of the engine, and the other constant. The combined operation of these forces regulates the position of the balls, and they are connected with the throttle-valve so that an opening for the admission of steam is made to increase as the governor-balls fall down, and to diminish as they rise, thus regulating the quantity of steam, and thereby the engine's speed.

Figs. 318 and 319 are front and side elevations of the governor; and Fig. 320 a vertical section of its standard or supporting pillar, which is bolted upon the planed bed of the engine. Brass bushes are fitted into the upper and lower ends in which the vertical governor spindle revolves.

Figs. 321 and 322.—Pendulum and ball; two views of the former and one section of the latter. Inside the ball is a slightly enlarged cavity, so arranged that by filing the ends of the square hole it will fit the corresponding square part of the pendulum-rod, without the labour of filing the entire hole.

Figs. 323 and 324.—Two views of the link connecting the pendulum and sliding-block.

Figs. 325, 326, and 327.—The brass cap and sliding-block, shown partly in section and elevation, with one plan which suits almost exactly for both.

Figs. 328 and 329.—Throttle-valve rod, with a screw to lengthen or shorten it, and so adjust the working of both governor and throttle-valve to each other.

Figs. 330 and 331.—Lever, made of brass, with two crescent-shaped pieces of steel to fit between the sliding-block collars, and transfer its movement to the throttle-valve lever, represented in the preceding lesson (Fig. 308).

Fig. 332.—Pin for slide-block lever and steel pieces.

Figs. 333 and 334.—Support for the above lever.

Fig. 335.—Pins for cap, slide-block, and pendulum, all made of steel, or of wrought iron case-hardened—that is, coated with steel by a chemical process.

Fig. 336.—Similar pins for the pendulum.

Fig. 337.—The vertical spindle to carry the pendulum, made of iron, except at the lower end, which is steel.

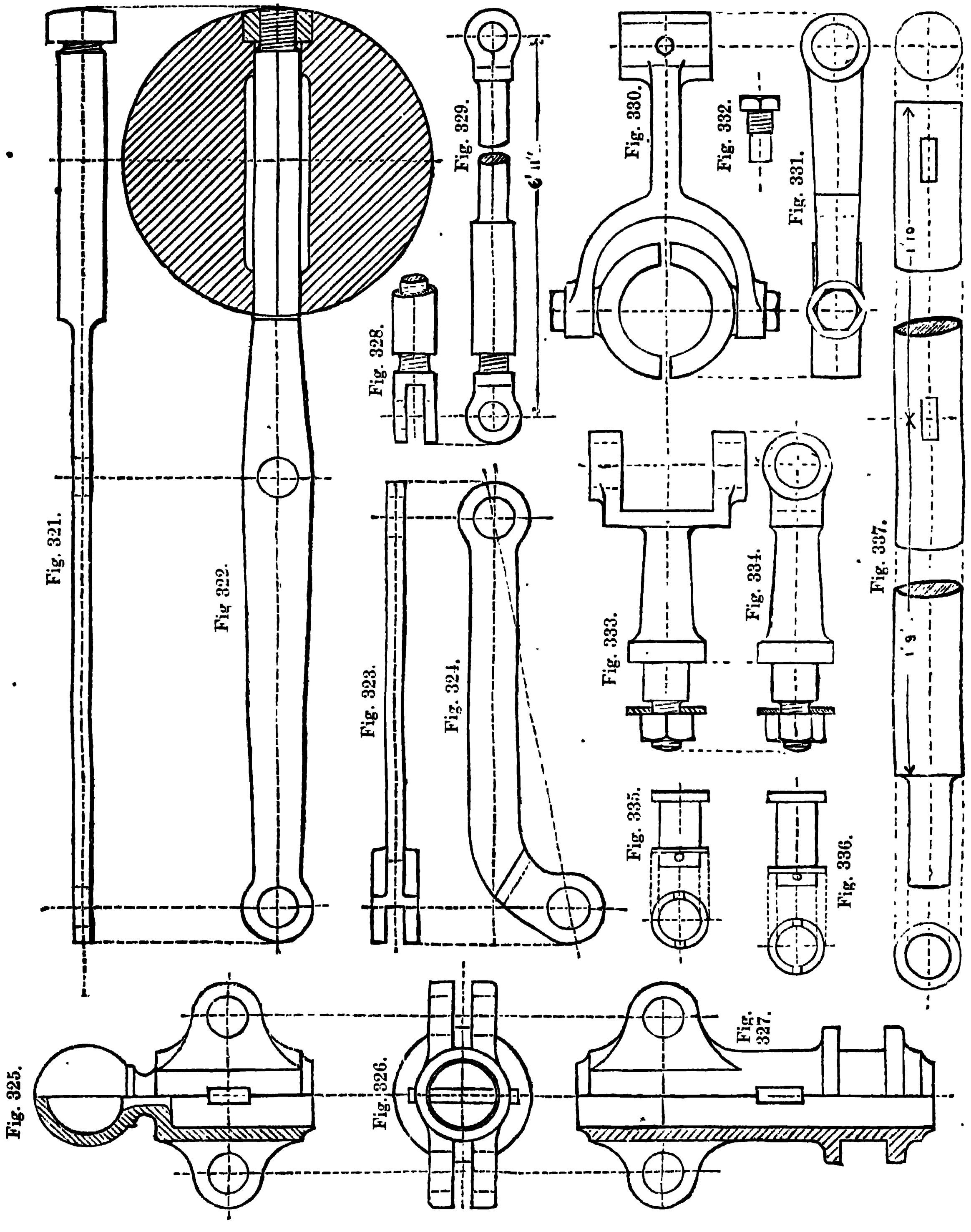


Fig. 321.
Fig. 322.
Fig. 323.
Fig. 324.
Fig. 325.
Fig. 326.
Fig. 327.
Fig. 328.
Fig. 329.
Fig. 330.
Fig. 331.
Fig. 332.
Fig. 333.
Fig. 334.
Fig. 335.
Fig. 336.
Fig. 337.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XI.—CHARLES HUTTON, LL.D.

BY JAMES GRANT.

CHARLES HUTTON, one of the most eminent mathematicians England has produced, was born in 1737, during the reign of George II. His parents were in humble circumstances, and very poor; they toiled early and late, and seemed only to exist to carry on that endless warfare with indigence which is all the needy know the word "life" to mean. He lost his father in boyhood, but having picked up a smattering of education, together with the science of measurements, he commenced in his eighteenth year to teach mathematics in the village of Jesmond, near Newcastle, and while there became so close and zealous a disciple of the Methodists that he even ventured, not only to write sermons, but to preach them to the people. This religious enthusiasm left him, however, on his removal to Newcastle, whither he was drawn by the increasing number of his pupils and his own growing proficiency as a teacher; and among those who attended his classes he had the pleasure to reckon the late Lord Chancellor Eldon. He found time for investigation and composition amid the multiplicity of his occupations, and in 1764 published a treatise on "Arithmetic and Book-keeping," for the use of schools. Since then it has gone through many editions; but it may be interesting to mention that in printing the first one, to supply the proper mathematical types, which would not then be found in a provincial town like Newcastle, Hutton had with his own hand to fashion, by the aid of a penknife, on the reversed ends of old types, all the algebraical characters used in the vulgar fractions and other parts of his treatise.

A more elaborate and abstruse work, "A Treatise on Mensuration in Theory and Practice," next occupied his leisure time. Prior to this publication, the works on mensuration used in seminaries were those of Hawney and Robertson: the former, inaccurately and inelegantly written, showed few attempts at theory; the latter, a more correct and perfect work, was limited to the exhibition of rules and examples. There had been from an earlier period, especially since the invention of fluxional analysis, many treatises and books relating to rectifications, quadratures, and cubatures written by learned men at home and abroad; but to collect, combine, and reduce all these to order and method, to expunge what was erroneous, curtail what was verbose, elucidate what was obscure, and develop practical results with perspicuity, became the task of Hutton, whose quarto volume, which appeared in 1770, was a masterpiece of its kind. Fortunately for him, about this time the Professorship of Mathematics in the Royal Military Academy at Woolwich became vacant, and the Master-General of the Ordnance (the Marquis of Townsend) directed that any individual who, at a public examination, should prove himself qualified to discharge the duties of that chair should be appointed to fill it. Colonel Edward Williams, a scientific officer of the Royal Artillery, now urged Hutton to present himself as a candidate; and, though naturally diffident by habit, he travelled in a somewhat humble way from Newcastle to Woolwich, a distance of 300 miles (a long journey in those pre-railway times), to undergo the required examination. This was conducted by Colonel Henry Watson, the translator of Euler's "Treatise on the Construction of Ships;" Bishop Horsley, the editor of Newton's works; and Dr. Maskelyne, the Astronomer-Royal; but to none of them was Hutton known save by name, and many learned and influential men figured among the competitors, all of whom were examined separately, so that no one could avail himself of the information possessed by the others.

The examination, a very fair and impartial one, lasted a whole day, till late in the evening, and at its conclusion each candidate received a great many extremely difficult problems in the most abstruse parts of mathematical science to solve, and a week was given them to do so, when they were to appear at Woolwich again. Though by his humble circumstances Hutton was debarred the use of many books and other assistance which the other competitors could command, at the conclusion of the examination he triumphed over them all, and by the examiners was unanimously recommended to the Master-General and Board of Officers, and he was highly complimented "on account of the very able manner in which he had answered all their questions, and on account of his very extensive reading and acquirements."

The University of Edinburgh, where then the famous Dugald Stewart and Dr. Matthew Stewart were joint Professors of Mathematics, now conferred upon him the degree of LL.D.; he was elected a Fellow of the Royal Society, and in January, 1779, was appointed its foreign secretary, an office which he held till 1783.

The first edition of his "Compendious Measurer" was issued in 1784, and was the popular abridgment of his quarto treatise on "Mensuration;" this has gone through many editions since, and was generally adopted in all English schools, the elaborate demonstrations being omitted, while the rules, examples, and applications are retained.

In 1785 he produced a more profound and copious work, entitled "Mathematical Tables," containing hyperbolic, common, and logistic logarithms, together with sines, tangents, secants, and versed sines, both natural and logarithmic. To these were added many tables useful in mathematical calculations. This work, a thick royal octavo, was occasioned by the extreme inaccuracy of the logarithmic tables of Sherwin and Gardiner, and he introduced many striking improvements in the resolution of plane and spherical triangles; but the most valuable portion of it is the extensive and learned introduction which he prefixed to the tables. It contains a fair and impartial history of early trigonometrical writings and tables, natural and logarithmic; and the inventions and improvements are clearly traced, and assigned to their proper authors. The peculiarities of John Napier, of Merchiston (original inventor of the logarithms), of Briggs, of Kepler, Gregory, Mercator, and Newton, are carefully discerned, and an immense amount of labour and deep reading displayed.

In 1786 he issued a quarto volume of "Tracts, Mathematical and Philosophical," which proved of great value alike to the man of science and the mechanic; and in the following year he began the preparation of his "Mathematical and Philosophical Dictionary." After nine years of labour, it appeared in 1796, in two great quarto volumes, and its value was at once acknowledged by the British public. Though chiefly compilation, it contained much that was alike new and original, and exhibited great patience, research, and impartiality, with considerable historical disquisition, particularly in the elaborate memoir of algebra. Of the most eminent mathematicians and philosophers he gives short biographical sketches, which are often spirited, and always truthful. It was universally declared to be "a work which the student of mathematics and of natural philosophy may consult with pleasure, and always with considerable advantage."

His "Course of Mathematics for the use of the Cadets in the Royal Military Academy" appeared in two octavo volumes in 1798, and has since gone through many editions. To this a third volume, written in conjunction with his friend Dr. Gregory, was issued in 1811. From 1803 to 1809 he had been employed, in conjunction with Drs. Pearson and Shaw, preparing an "Abridgment of the Philosophical Transactions of the Royal Society of London, from the Commencement, in 1665, to the End of the Last Century," a laborious and most important work, for his share in the execution of which he received £6,000. The "Abridgment" extended to eighteen thick quarto volumes, and was published in monthly parts, four of which constituted a volume.

After having filled with honour and popularity the office of Professor at Woolwich for thirty-four years, in the summer of 1807 he felt himself compelled to resign it, and retire from active life, having suffered much from a pulmonary complaint during the preceding winter and spring; but on his retirement the Board of Ordnance assigned for his past services, and as a testimony of regard, a pension of £500 per annum; and as he had previously amassed a handsome fortune by the profits of his literary and scientific exertions, he fixed his abode in London. In retirement his pen was never idle, but was constantly employed in the preparation of learned papers. Thus, five years after leaving Woolwich, he published his "Tracts on Mathematical and Philosophical Subjects," comprising, among numerous important articles, the theory of bridges, with several plans of recent improvement; also the results of numerous experiments on the force of gunpowder, with applications on the modern practice of artillery.

With many corrections and improvements, these volumes contain several of his detached essays and tracts previously enumerated, together with the "History of the Writings and Investigations in Trigonometry and Logarithms," as published in the introduction to his "Mathematical Tables," and the "History of the Discoveries and Inventions in Algebra," which was first published under the word *Algebra* in his quarto dictionary. Most of the "Tracts," however, were new; among those were a clear and methodical narration of his interesting experiments in gunnery and projectiles.

The extraordinary and marked omission of Hutton's name by the Marquis Laplace, when speaking of the determination of the mean density of the earth, led to some correspondence between him and that learned French philosopher, in the years 1819 and 1820, for Hutton's feelings were undoubtedly wounded. His letter, which was published in the "Philosophical Magazine" of February, and in the "Journal de Physique" of April, 1820, remained unanswered for many months; but ultimately, in the "Connaissance des Temps," the marquis did ample justice to the learned Englishman, after he had described the nature and difficulty of computation relative to the earth's density, by adding, "All this was executed in the most satisfactory manner by Dr. Hutton, an illustrious mathematician, to whom the abstruse sciences are indebted for numerous other important researches."

A severe cold which he caught in 1822, by some unavoidable exposure, ended in a pulmonary complaint, which made speedy inroads on his constitution. His physical strength declined rapidly, and in his actions, conversations, and letters he showed a knowledge that his latter end was drawing nigh. Till near his death he yet retained the entire possession of his powers and all his fine perceptive qualities, and was able to go up and down stairs.

"On Friday, the 24th of January, 1823. only three days before the termination of his life," wrote his friend and successor, Dr. Olinthus Gregory, "I visited him, at his own request, in consequence of a communication which he had received from the Bridge House Committee, relative to the proposed new bridge in place of London Bridge. He could then see to read writing of the usual size without spectacles, and heard very well all that I said, on my aiming at a rather slow and distinct enunciation. His respiration was difficult, as it had been for some time; but on the whole I thought him better than when I had seen him a week before. Our chief conversation was on the subject of his letter from the City. He expatiated with his usual perspicuity and accuracy upon the theory of arcuation, the relative advantages and disadvantages of different curves selected for the intrados, the most judicious construction of centreing, etc. He then passed to the history of the erection of Blackfriars Bridge, sketched briefly the principles developed on that occasion by Mr. Simpson, his predecessor at Woolwich, and alluded to the scientific qualifications of Mr. Robert Mylne, the architect of that edifice—for which his designs were chosen before those of twenty other competitors, from their great superiority in the mode of centreing—but the effort greatly exhausted him, and compelled me to relinquish my intention of conversing with him on another topic. He entreated me to visit him that day week, and I most cheerfully assented, hoping the interview would have its peculiar interest."

Before "that day week" all was over, and the great mathematician had solved the problem of Time and Eternity; for on Saturday he became worse, on Sunday worse still. He sank into a comatose state as evening drew on, and expired at four o'clock on the morning of Monday, the 27th of January, 1823.

SANITARY ENGINEERING.—I.

GAS: ITS MANUFACTURE BY PUBLIC COMPANIES.

By W. J. Piper.

The first records that we have of the utilisation of coal-gas for lighting purposes date from about the middle of the seventeenth century; before that time there are many legends, as we may call them, of the rising of inflammable gas from the earth. The sacred fires in the East, and in some parts of Europe, doubtless drew their supplies from this source; and, curiously enough, the Chinese claim the honour of having used what may be termed natural gas for illuminating purposes many centuries ago. About the middle of the seventeenth century, some papers were read before the Royal Society upon the discovery of natural gas in Lancashire; and about the year 1800, or a little earlier, some of the more scientific and enterprising firms of the day had adopted "gas" as the ordinary means of lighting their workshops and factories. Of course, they made it themselves, as no public companies were in existence, and we may mention as an instance the factory of Messrs. Boulton and Watt, at Soho.

The first Act of Parliament creating a chartered company was passed in 1810, and in 1813 Westminster Bridge was lighted with gas. Illuminating gas for commercial purposes has been made from coal, resin, oil, peat, and wood, with varying results as to economy and efficiency; but, as far as the present manufacture is concerned, *coal-gas* is the only source of supply, and it is to some explanation of the methods employed that the present paper is devoted.

The simple principle upon which all gas-lighting is founded is the exposure of coal to heat sufficient to produce combustion, in air-tight vessels—*i.e.*, to decompose the coal by heat, without the admission of the external air. The volatile portions have an outlet provided for them, which conduct them to receptacles for future use, and the solid matter remaining (coke) is not without its commercial value. Chemically, all the materials from which gas is made consist of carbon, hydrogen, and oxygen, in various proportions; and we may take it that the greater the per-centage of hydrogen the greater the illuminating power of the gas evolved. Cannel coal is, for this reason, the parent of a gas of much higher illuminating power than ordinary Newcastle coal, though, of course, the difference of price renders it comparatively expensive; while gas made from oil, especially some of the recently discovered hydro-carbons, has still greater brilliancy. This particular branch of the manufacture, however, may be considered almost in its infancy, and has not yet been adopted by any public company to such an extent as to warrant notice at the moment.

The first portion of the process, then, is to submit coal to the action of heat in an air-tight vessel, commonly called a "retort." These are made of various forms and various materials—wrought iron, cast iron, and earthenware—each having its peculiar characteristics as thus employed. Wrought iron, at high temperatures, undergoes rapid oxidation, as does cast iron, though possibly in a less degree, the latter being far more liable to fracture; earthenware, while perfectly free from oxidation, not being so good a conductor as the other materials.

The usual forms of the retort are circular, oval, or bean-shaped, but the form now in most common use may be described as the D form, the lower side being slightly curved upwards. 18 inches wide and 12 inches high, or perhaps rather larger, may be taken as an ordinary working dimension, and from 7 feet to 10 feet long, according to circumstances. A group of these retorts, from five to six in number, or more, as the case may be, are set in a furnace, and filled with coal from the end, and as soon as they are charged a gas-tight lid is screwed on the front of each. From the top of the front end of each retort rises what is technically called the stand-pipe—*i.e.*, the pipe through which the volatile products of combustion, *i.e.*, what may be called the crude gas—arise.

Many other forms of retort have been used. Some, in the North, have been constructed of wrought iron, with cast-iron bottoms, 4 feet or more wide and 1½ feet high, working off a ton of coals in about twenty-four hours. Stourbridge clay is now very largely used for the purpose, of course, in much greater thickness of material than either wrought or cast iron. To show, however, that it is specially applicable, we may mention that retorts have been made of it 10 feet long and 3 feet wide. We believe that it is gradually superseding the other materials for general use.

The arrangement and grouping of these retorts varies, of course, almost *ad infinitum* with the extent of the works of which they form part, and with the fancy of the engineers by whom they are designed.

But now to proceed. The retorts being charged and in working, what is the quality of the gas delivered by the stand-pipes? This, of course, varies also with the quality of the coal employed, and the temperature to which the retort is subjected. The higher the temperature the more volatile the product, and the larger the solid remnant; while too low a temperature, though leaving less residue, develops a large amount of an intermediate and comparatively useless material, viz., tar; and it is to hit the exact medium between these points that the attention of the engineer is directed, as that is the most profitable gas that has the largest illuminating power. The gas evolved at too great a temperature approaches somewhat in its proportions to the natural sulphuretted hydrogen, which burns with considerable heat, but with little light; and therefore the main object is to release from the retort the gas the moment it escapes from the coal, before it is subjected to the further heat which would reduce its illuminating power.

We will suppose, however, this result to be successfully obtained, and that the gas in the stand-pipe is as good as can be made. It is not yet fit for use, as it contains vapour of naphtha, and tar, some steam, and compounds of ammonia, with other impurities, which, if it were sent forward at once for use, would condense in the pipes and interfere with the supply, or create an offensive smell in the process of combustion. This is specially the case when sulphuretted hydrogen is present, as is often the case; while when carbonic acid enters into the composition of the gas its lighting power is much reduced. The next process is as under.

The stand-pipes above described are generally conducted into a cylindrical receiver, into which their ends are reversed, and the condensation of tar and other matter, viz., coal-oil, is allowed to fill this receiver above the level of the ends of pipes thus introduced. When not at work they are thus hermetically sealed, and it therefore becomes possible to draw the charge of any particular retort without interfering with the others. From this receiver there is an overflow pipe to the tar cistern, so that the contents are always kept at a certain level. The next point is to reduce the temperature of the gas, which at this point of course is high, to something not much exceeding the external air. This is done by passing it through a refrigerator, or condenser; and in the course of this process it deposits all those elements which it could not retain in suspension at the ordinary temperature of the atmosphere. Sometimes currents of cold air only are employed, and sometimes a circulation of cold water through what may be called the double jacket of the condenser, which takes various forms in the hands of different engineers; the result, however, being in all cases the same—that the products of condensation thus deposited are led away and deposited in the tar cistern; and the gas, thus reduced to about the ordinary atmospheric temperature, has next to be subjected to the action of the purifier, which has to remove whatever sulphuretted hydrogen and carbonic acid remain in excess. Lime, either wet, in the form of milk of lime, or else dry, is the material that has been up to this time most usually employed, but now some forms of oxides are coming into use, and the quantity of lime is regulated by the quality of the gas. Supposing the per-centage of impurity to be eliminated is 5 per cent., 15 pounds of lime to the 1,000 cubic feet of gas is considered to be about the proper proportion, and, of course, the various calculations as to bulk, etc., follow from the size of the works.

There are various tests for ascertaining the purity of the gas after it has passed through this process, into which we shall go further in detail in future papers. The purifier is, in some cases, a cylindrical iron vessel, so arranged that the milk of lime is continually stirred by machinery provided for the purpose, and when it has answered its purpose—*i.e.*, when too foul for further use—there is the necessary provision for the removal of the foul and substitution of a fresh material.

Before, however, the gas enters the purifier, it has to pass the exhauster, an apparatus invented for the purpose of relieving the reverse pressure exerted upon the retorts by the passage of the gas through the cylindrical receiver, or hydraulic main, and other portions of the apparatus. The means are merely mechanical, consisting of various applications of valves, kept constantly in motion by steam-power. This has the effect of reducing leakage in the retorts, if there is any flaw, and of producing a more favourable condition of combustion; as it has been ascertained that if subjected to heat under pressure the illuminating power of the gas in process of evolution is much diminished.

Another method of purifying is by dry lime, the gas being passed through a series of sieves upon which it is spread; and another process has been patented by which a sort of Archimedian screw is kept constantly revolving in the lime liquid, and the gas and milk of lime being far more thoroughly mixed than by either of the previously described methods, a more perfect result is obtained.

The gas being thus made, cooled, and purified, it is necessary to store it, to provide for the necessities of consumption, so that it can be distributed as required at an equable pressure; and for this purpose are constructed the large circular gas-holders, popularly and erroneously called gasometers, which are the familiar and distinguishing feature of all large gas-works. These are constructed of wrought iron, and may be compared in form to an inverted tumbler, as they must be invariably provided with a tank of water, into which they subside when out of use. Their size is in proportion to the gas required to be consumed within a certain time, and there should always be a considerable margin, in case of any accident to the retorts or other portions of the apparatus. The action is as under. They are suspended and confined in their position by columns, generally of cast iron, on which are pulleys, with chains attached, to which are heavy counterbalanced weights. When empty they are down at the level of the water, or nearly so; as they fill, the pressure of the gas gradually lifts them to the extent of their construction. The cisterns in which they work are sometimes built of brickwork, and sometimes of masonry; and sometimes, when the situation of the works renders this class of building difficult, a double cistern of wrought iron or cast-iron is substituted, between the inner and outer skin of which the gas-holder travels up and down.

A recent improvement in gas-holders is the introduction of the telescopic principle. If made in a single cistern and piece, great space is required on the plan, in proportion to the quantity of gas stored; but by the introduction of the telescopic principle, three times the storage can be obtained upon the same extent of ground, the three cisterns, one above the other, subsiding when empty into the height of a single one of the three; while when full, with gas-tight joints at the junction, they are drawn out to their full height like the joints of a telescope. It is rarely necessary to change the water in a gasholder, because its surface soon becomes covered with a stratum of coal-oil, which prevents evaporation to a great extent.

Having thus described the manufacture and storage of gas, we now proceed to the question of its distribution by means of gas-mains; and, of course, the first question is the quantity of gas required to be delivered within a given time. This has frequently been made the subject of experiment, and the results have been tabulated: we will, however, quote a figure or two, showing the results which have been thus ascertained. A pipe of about 4½ inches in diameter, and 1,000 feet long, will deliver 2,000 cubic feet of gas per hour, while one of 9 inches, or rather more, 2,000 feet long, will deliver 6,000 feet per hour; the formula being, that under similar circumstances of pressure, the powers of transmission of different pipes are directly in proportion to the squares of their diameters, and inversely as the square root of their length.

Cast-iron socket-pipes are generally used for the principal mains, the joints formed with a luting of clay run with lead, driven home by a mallet and chisel. The lesser pipes for house supply are mostly drawn pipes of wrought iron, while the smallest pipes—viz., those which serve only single burners—are usually of tin or pipe metal. Into the detailed description of various kinds of burners, gas meters proper—*i.e.*, machines for measuring the quantity of gas burnt—gas regulators, for controlling the pressure, and other similar inventions, we shall enter in some future papers. The industrial aspect of the question is a most important one; it is no exaggeration to say that hundreds of millions of pounds are at the moment invested in plant for the manufacture of coal-gas. And to give an idea of the extent to which enterprise is developing the system in this country alone, we may mention that in the session of 1870, there were forty gas bills introduced into Parliament, authorising an additional expenditure in that year only of more than £3,000,000, while in the present session, 1871, the number of similar bills has increased to forty-five.

Such is the importance of the manufacture, of which a rough outline only has been given, but which is sufficient to show the method adopted in its manufacture in retorts at the gas-works, its storage in gas-holders, and its distribution for general consumption through pipes of various sizes.

MINING AND QUARRYING.—IV.

BY GEORGE GLADSTONE, F.C.S.

COAL.

WINNING—BY LEVEL—BY SINKING—CHOICE OF LOCALITY—SINKING THE SHAFT—FORM AND FITTINGS—UNDERGROUND PLAN OF MINE—POST AND STALL, AND LONG-WALL SYSTEMS.

THE mode of getting at the coal depends upon the nature of the ground, and the level at which the workable seams occur. The simplest case is where the country is hilly, and the seam to be worked extends above the level of the valley. It can then be reached by driving a horizontal gallery or small tunnel from the hill-side until it cuts the seam. A miner, however, would not adopt a dead level, but would make it rise gently from the entrance, so that the water should not collect in the workings. Thus the expense of pumping would be saved. A tramway laid along the gallery would connect the productive part of the mine with the outside world.

The majority of mines are, however, below the surface, and the coal can only be reached by sinking. In this case the excavation, instead of being horizontal, is perpendicular, and is called a *shaft*. The sinking of a shaft is often a tedious and very expensive operation, and before commencing it has to be well considered where to place it. A deep shaft, including engine-power, has been known to cost £100,000, and to occupy ten years to complete.

The shaft in a deep mine being the centre from which all the subsequent operations ramify, it should be put in the most convenient situation for the underground workings. If the ground is broken by faults, it should be removed as far as possible from them; and as a general rule it should be towards the dip and not the outcrop, because the pit should drain to the bottom of the shaft, and the coal-laden trucks have to be brought to the same point.

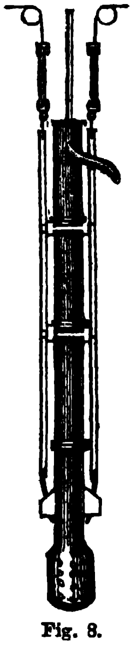


Fig. 8.

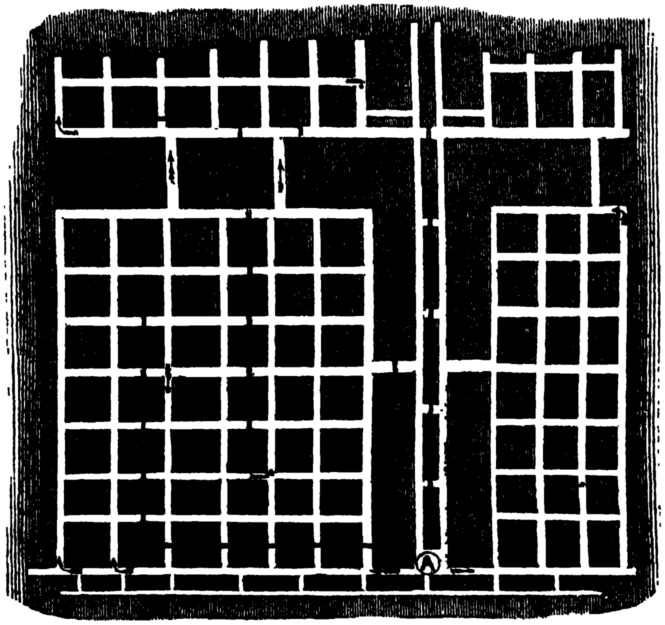


Fig. 9.

The spot being determined, we will suppose a first-class deep pit to be opened up. In order to economise expense, the one shaft must serve for pumping, ventilation, the ascent and descent of the miners, and the bringing of the coal to the pit's mouth; though in very extensive workings a second shaft would have to be sunk.

The best form of shaft is the circular, that being the strongest in proportion to the quantity of material employed. It is usually divided by brattices into four equal segments. One of these is devoted to the pumps, a second to ventilation, and the other two to the ascending and descending coal buckets. The diameter of such a shaft is usually about fifteen feet.

The principal difficulties connected with the sinking do not consist in the hardness of the rock which has to be excavated, because that is a mere question of labour and the use of gunpowder. When very hard, several holes are drilled near the outer part of the circle and charged; the workmen can then come up out of the way of danger, and all the charges be fired simultaneously by an electric battery. Water is the article which gives the workmen most trouble. They are sure to cut feeders of water, especially at the junction of different layers of rock, and often beds of very wet sand, which are the most troublesome of all. To guard against these eventualities, it is always necessary to have pumping power ready, and in piercing through a new district powerful engines for this purpose should be provided, as it is better to have a waste of power than have the workings drowned through inability to keep the water under.

The first portion of the shaft, consisting of loose or broken materials, and liable to contain at times a good deal of water, generally needs to be "tubbed." The process of tubbing consists of filling in the sides of the shaft with thick staves of oak, well wedged together in a strong frame, so as to form water-tight sides. Iron has of late years been substituted for wood with great advantage. Cast-iron tubbing is made in segments corresponding in curvature with the size of the shaft, having the flanges by which they are fastened together on the outside. As soon as any wet and soft stratum is approached, the segments are fixed together round the sides of the shaft, and the upper part loaded with heavy weights, so that it sinks down of its own accord as the labourers dig out the mud or sand from the midst. Any number of rows of these segments can be fastened one upon another according to the depth required.

During the process of sinking the pumps are so arranged that they can be let down gradually as the work proceeds. They hang upon tackle passing over pulleys, and descend by their own weight as fast as the excavations will allow; a flexible hose is attached to the spout in order to convey the water to the cistern. The arrangement will readily be understood by reference to Fig. 8.

At every twenty-five to thirty fathoms a cistern is made in an excavation of the rock, and for that portion a permanent pump is then provided. In some cases lift-pumps, and in others force-pumps are used. They are in almost constant requisition as long as the colliery lasts, and in old workings, where a large area has been excavated, they are kept going night and day, as the amount of drainage increases steadily in proportion as the colliery is opened out.

Having thus sunk the shaft down to the seam which is intended to be worked, the coal is said to be *won*. The plan of working the mine has now to be laid out.

This has to be regulated by several considerations, the object being to remove as much of the coal as possible, but in such a manner as to secure a thorough ventilation of the mine, and the safety of the miner from the falling in of the roof.

The shaft A, as shown in Fig. 9, is sunk near the dip-head, so that as the workings are extended the water shall drain down to that point; and in order to collect it, a dip-head level, B B, is cut in the first instance. The first working gallery, C C, is then made, usually parallel to the other, extending from the pit bottom right and left. From this the galleries run up towards the outcrop in parallel lines, which, as they advance, are connected by others at right angles, so that the mine assumes the appearance of an underground city laid out upon a rectangular plan, the blocks of houses being represented by the unworked coal. No uniform system can, however, be adopted, as the plan of operations has to be modified according to the special circumstances of every mine. The diagram will serve as a specimen of what is called *panel-working*, with post and stall, from a single shaft, a plan rather common in the Newcastle district.

All workings may be considered as modifications of the *post and stall*, or of the *long-wall* system. The latter is more generally adopted in the midland counties.

We will take post and stall first It has other names, such as *board and pillar*, or in Scotland *stoop and room*. The pillars or blocks of unwrought coal support the roof, and the galleries between them being comparatively narrow, a system of ventilation can be arranged by closing up some of them with doors, which could not be accomplished were the mine worked irregularly, and with large open spaces. Upon the panel system the whole colliery is laid out in panels, of which one complete one and parts of three others are shown in the diagram, with thick walls of coal between each, perforated only here and there, just sufficiently for communication and ventilation. The whole mine being opened up in this way, the pitmen proceed to work out the pillars completely, beginning with those in the furthest corners, where the pressure from above is most divided. While these are being removed, pit-props of timber have to be inserted to support the roof. As each pillar is cleared the men draw out the props, beginning with the most distant one, and allow the roof to fall in, filling up the space with broken stone, which is then termed a *goaf*. One by one the pillars disappear, and the goaf extends, until the whole of the coal has been worked out of the panel, the panel walls in their turn being worked away as far as possible, so that very little coal need be eventually lost.

Upon the old system the passages used to be made much wider, and the pillars only large enough to support the roof; but that arrangement has several disadvantages. The whole of the weight being thus left to rest upon a small area, the pillars were sometimes forced down into the floor, which would bulge upwards and form a *creep;* or if the roof were tender, it would be apt to break away and fill up the passage, which would be a *sit*. These are both very difficult to cure, and are very objectionable, as they not only prevent the passage of the workmen, but also derange the systems of drainage and ventilation.

The two galleries D D, D′ D′, which run directly from the shaft towards the crop, are termed the *winning headway*, which is always carried rather in advance of the other workings. It is the main channel of communication, by which the coal from the more distant parts is brought to the pit bottom, and which also brings the heated air, after having made its circuit through the workings, to the upcast shaft. This headway is, of course, kept in effective condition throughout the progress of the mine, and is the last part that would be touched.

The principles upon which the ventilation of such a colliery would be conducted are indicated by the arrows, the passages being closed by doors where the cross lines occur. There is no difficulty in establishing a current of air in a deep pit, because the temperature at the bottom of the shaft will be naturally much higher than at the top, and the shaft being divided into segments, the hot air is made to pass constantly up one of them (called the upcast shaft) by having a furnace at the pit bottom connected with that segment, while the fresh air from above coming down the downcast shaft, is conducted at once into the galleries.

Upon the long-wall system, the dip-head level, the winning out walls right and left, and the winning headway must first be made as before; and then commencing at some little distance from the shaft, long galleries would be driven parallel to one another. The miner then proceeds at once to clear out the coal between each gallery, allowing the roof to fall in as he proceeds, except wherever it may be necessary to keep a passage open for the sake of ventilation. The mine thus presents a series of long walls, and the pitman holes or undermines the coal with his pick as deep as he can reach right along the line of the wall, when the pressure from above—there being no support on the other side—readily breaks the coal up; or if it should prove too firm it is broken down with wedges. On this plan, therefore, the miner is constantly working with a falling roof almost immediately behind him; but upon the whole it is not found to be more dangerous than the other system, while it is rather more economical of coal. If the roof should prove to be tender, it is shored up with props to a sufficient distance to protect the men, or they make a supporting wall of the blocks of stone which can be got out of the goaf. Those passages which require to be retained are permanently walled up with stone, so as to keep the roof entire. In this mode of working the air-passages are frequently made to cross, one being carried under the other through a little tunnel. By the long-wall method the workings are carried from the shaft outwards, the coal-seam being thoroughly cleared as the work proceeds; but as it is of the greatest importance that the shaft should not be liable to the least disturbance, which might easily stop the colliery altogether, and endanger the lives of the men, a solid mass of coal is always left untouched immediately round the pit bottom.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XII.—GENERAL DUDD DUDLEY.

BY JAMES GRANT

THIS celebrated Cavalier officer and faithful adherent of Charles the First, the inventor of iron-smelting by *pit-coal*, was born during the reign of Queen Elizabeth, in 1599.

Prior to his time, iron had been chiefly imported by the Steel-yard Company of foreign merchants in Upper Thames Street; the great coal resources of England were yet undeveloped; her old forests of the Saxon times were disappearing fast; and the severe restrictions enforced by the Legislature against the use of wood in iron-smelting had the effect of nearly extinguishing the manufacture, as the old iron-smelters maintained that it was impracticable to reduce the ore by any other process than by means of charcoal-wood. Sturtevant, a German skilled in mining operations, suggested the adoption of earth-coal and brush-fuel in a "Treatise" which he wrote; but Dudd Dudley was the first Englishman who, on finding that his furnaces were failing by the want of wood, adopted pit-coal in its place, and in spite of all local prejudice.

This speculator was the natural son of Edward Lord Dudley (of Dudley Castle in Worcestershire) and of Elizabeth Tomlinson; he was one of eleven children by the same mother. All these were educated with care by Lord Dudley, who bestowed Netherton Hall upon the eldest brother of Dudd, while their sisters were all married well among the best families in the county. After completing his studies at Baliol College, Oxford, Dudd, who was a special favourite with his father the earl, was sent by him in 1619 to take charge of two forges and an iron furnace, possessed by him in the chase of Pensnet, Worcestershire. Finding wood scarce, he immediately employed pit-coal as a substitute; and so successful was the result of the first essay, that he was resolved to persevere in its use. Though the portion produced by the new process was somewhat little—being about three tons per week from each furnace—he confidently expected that increased experience would enable him to double the quantity; "and at all events, he had succeeded in proving the practicability of smelting iron with fuel made from pit-coal, which many before him had tried in vain."

Through his father the earl, who was then in London, he sought for and obtained from King James a patent for his invention; and it was issued in Lord Dudley's own name, on the 22nd of February, 1620. In addition to his manufactory for iron at Pensnet, Dudd Dudley now erected another at Cradley in Somersetshire; and a year after the issue of the patent, he was able to send, in obedience to the king's command, a great quantity of this new iron to the Tower of London, where its qualities were fully tested for various purposes. Dudley was now on the high way to fortune, and there was every prospect of the new method of smelting becoming fairly established as a staple manufacture, when calamities none could foresee fell upon the inventor, to the great joy of many rival iron-smelters, who either envied him the possession of his patent, or adhered obstinately to the use of charcoal.

On Mayday a great flood swept away his works at Cradley, and damaged all the district of Stourbridge, where the river rose so high that all the lower portion of the town was submerged by water, and the hostile iron-masters now hoped "that there was an end for ever of Dudley's pit-coal iron." However, he soon repaired his forges and furnaces, and had them all in working order for supplying the market. His rivals now endeavoured to influence the king against him; hence he was again ordered to send to the Tower a fresh supply of his iron for peculiar testing; and on proof, it was found fit for the manufacture of muskets, carbines, ship-bolts, and so thoroughly excellent in quality, that his enemies were silenced till the year 1624, when they made incredible exertions to have his patent abolished by a statute which was passed in that year, for sweeping away old monopolies; but all they could accomplish was a limitation of the said patent to fourteen, instead of thirty-one years. Dudley now poured vast quantities of iron into the market yearly, and also manufactured all manner of cast-metal ware, brewing cisterns, pots, pans, mortars, and weights; but notwithstanding his complete temporary success, more misfortunes of a serious nature were in store for him.

A general combination of his rivals, who succeeded in fastening vexatious law-suits upon him, drove him in succession from his works at Cradley, from others he had erected at Himley in Staffordshire, and also from a large new furnace he erected near Sedgeley, and had provided with unusually large bellows. The latter works were barely completed, when a mob of rioters, instigated by the charcoal-smelters, cut the great bellows to pieces, tore down the stone furnace, and destroyed the machinery, laying the whole place in hopeless ruin, and from that day Dudley had no peace. His creditors swooped down upon him, and he was sent to London a prisoner, and detained in the Comptoir for debt, leaving the exulting charcoal-smelters in full possession of the field.

Charles I. was now upon the throne, and that humane king took pity on the unfortunate inventor whose deep-laid ingenuity and persevering industry had availed him so little; and on Dudley's release from prison he granted him a renewal of his patent in 1638, three other persons—a Sir George Horsey, David Ramsay (a Scot), and Roger Foulke—joining him as partners, and providing the requisite capital for smelting on an extended scale; but barely was the patent secured when the great Civil War broke out, and all over the land the plough and the hammer were relinquished for the sword and musket. Dudd Dudley now attached himself to the fortunes of his patron the king. In the year prior to these troubles he had accompanied, in some official capacity, the Marquis of Hamilton, who was sent by Charles as Lord High Commissioner to the Parliament and Church of Scotland; and from Edinburgh he would seem to have seen a portion of that then *terra incognita*, the Highlands, and also to have visited a Sir James Hope at the Leadhills near Glengower, a wild and desolate region still, but where lead mines are yet worked with success and profit.

In 1639 Dudley accompanied Charles in his rash invasion of Scotland, a movement which the Scots anticipated by entering England with 4,000 cavalry and 20,000 infantry under Marshal Leslie. Dudley was present at the defeat of the king's troops at Newburnford on the Tyne, where Charles's royal standard was taken and many men killed on both sides.

In 1640 Dudley was appointed Surveyor of the Armoury; but being too poor to pay the patent fees, another was appointed in his place; yet he remained staunch to Charles; and when the latter left London, after the fall of his evil counsellors Laud and Strafford, he accompanied him. He was with him before Hull, the first town in England which closed its gates against the ill-fated monarch; he was at Nottingham when the royal standard was raised, and at Coventry when the people fired on the king's troops from its fortifications, which then consisted of strong walls and twenty-six towers; he was present at the battle of Edgehill, the first regular action between Charles and the Parliament in 1642, and in all the other engagements of that unhappy year.

After serving as major in Sir Francis Worsley's regiment, in 1643, he acted as military engineer, and after strengthening the fortifications of Worcester and Stafford, where the old castle of the Conqueror's time was garrisoned by the Royalists, he furnished them with ordnance. After the storming of Lichfield he was made colonel of dragoons, a species of force which then, and for long after, fought either on horseback or foot; and in this capacity he escorted Queen Henrietta to Oxford, where, in 1644, the king summoned such members of both houses as were devoted to his interests. Dudley afterwards served at the siege of Gloucester, which was then defended by a strong wall, afterwards demolished by Charles II., and with Sir George Lisle he led the vanguard at Newbury. Lisle, the son of a London bookseller, was distinguished for his bravery, and was knighted by the king on the field. Dudley next served at Newport under the famous Sir Charles Lucas, and the year 1645 saw him appointed general of Prince Maurice's train of artillery; and in this capacity, true to his old smelting instincts, the iron counties being at that time in the hands of the cavaliers, he turned his practical experience to account by the forging of small drakes (*i.e.* 6-pounder field guns) of bar-iron for the king's service.

When Goring raised his standard in Essex, and was besieged in Colchester, Dudley endeavoured to join him at the head of 200 horse, raised mostly at his own expense. These, while posted in a wood near Madeley, were attacked by a body of Cromwellians, and were all killed, dispersed, or taken prisoners. Dudley, two majors (Elliot and Harcourt), a captain, and a cornet were taken, stripped almost naked, and conveyed with every indignity to Worcester, where they were thrown into the common prison. Harcourt was severely scorched by gun-matches. Dudley, who had been wounded in the leg, and Elliot effected their escape, but were hotly pursued. Travelling only in the night, and hiding in trees by day, they reached London, after proceeding 111 miles on foot, only to be re-taken, and sentenced by the Committee of Insurrection to be imprisoned in the Gatehouse of Westminster, from whence they were to be taken on a certain day, and shot to death with other luckless Royalists then in the hands of Oliver Cromwell.

Ere this fatal day came Dudley was again free. During the time of sermon on Monday, the 20th of August, 1648, Dudley, Sir Henry Bates, and nine other captive cavaliers, succeeded in suddenly overpowering their warder, in breaking out of prison and making for the open country, when they dispersed, each one to shift for himself. Dudley's wounded limb sorely impeded his progress, and he had to proceed on crutches, and of course while penniless, through Worcester and Gloucester to Bristol, on one occasion having to remain hidden for three weeks in a hay-mow.

The king beheaded, his adherents dispersed or in prison, Dudley's career as a soldier was over. The estate left him by the earl his father, a place called Green Lodge, valued at £200 per annum, had become the prey of a Cromwellian named Major Wildman; his house in Worcester had been seized, and his wife turned into the streets; his iron-works were destroyed; all the offices he had held under King Charles were gone; and he was now menaced by destitution and starvation on the highway.

Poor though he was, he was still master of the secret process of smelting iron by pit-coal, and he lived on in the hope of one day turning it to account again. After the defeat of the Scottish Royalists at Worcester, the pursuit of their English brethren soon ceased, and Dudley, emerging from his lurking-place at Bristol, succeeded in inducing John Stone, a merchant, and Walter Stevens, a linendraper, both of that city, to join him as partners in a forge and furnace to be erected near it; but, unhappily, a quarrel ensued among them; the works were stopped; the concern was thrown into Chancery, and, of course, remained there hopelessly.

Major Wildman, a fighting preacher, had become possessor of Dudley's little estate, in the hope of extorting or discovering somehow his secret of iron-smelting; but in vain. He cut down all the timber, however, and demolished two mansions that were on it, and sold the materials.

At the Restoration in 1660 Dudley petitioned the king for a renewal of his patent, and for some compensation for the heavy losses he had sustained during the war. He failed to procure the former and also the latter, for Charles was besieged by similar petitions, and by applications of all kinds from England and from Scotland too. Undeterred by his bad success, however, he petitioned again that he might receive his rank in the Ordnance, be appointed Master of the Charter House in Smithfield, or to any living which would support him, for he was in his sixty-first year, and all that he had undergone had sorely injured his health; and as a reward for his perseverance he obtained the office of Serjeant-at-arms.

A few years later, he succeeded in ousting Major Wildman from his estate in the country, and resuming there the process of iron-smelting. He restored his works at Cradley, and erected three great forges at Green Lodge. For many years more he continued to prosecute the manufacture of iron, till eventually he retired to the village of St. Helens in Worcestershire, where he died in 1685, in the eighty-fifth year of his age, and was buried within the walls of the parish church. So closed a long and stirring life.

"Dudley's invention of smelting iron with coke made of pit-coal was, like many others, born before its time," says the author of "Industrial Biography;" "it was neither appreciated by the iron masters, nor by their workmen. All other schemes for smelting ore with any other fuel than charcoal made from wood were regarded with incredulity. As for Dudley's *Metalum Martis*, as it contained no specification, it revealed no secret; and when its author died, his secret, whatever it might be, died with him. Other improvements were doubtless necessary before the invention could be turned to useful account. Thus, until a more powerful blowing-furnace had been contrived, the production of pit-coal iron must necessarily have been limited. Dudley himself does not seem to have been able to make more on an average than five tons a week, and seven tons at the outside. Nor was the iron so good as that made by the charcoal; for it is admitted to have been especially liable to deterioration by the sulphurous fumes of the coal in the process of manufacture."

BUILDING CONSTRUCTION.—XVI.

ROOFS (*continued*).

The following terms are constantly used in relation to roofs, and the explanation of them here will be found of service to the student:—

Wall-plates are pieces of timber laid on the wall in order to distribute the pressure of the roof equally, and to bind the walls together. Were it not for wall-plates, the tie-beams of a roof or the joists of a floor would rest on single bricks, whilst the spaces between the joists would not in any way assist in bearing the load. The wall-plate lying on the whole length of the wall, therefore, spreads the pressure over all the bricks, and the trusses, or joists, rest on a frame of timber.

Trusses are strong assemblages of timber, generally of a triangular form, serving to support the purlins on which the common rafters rest. They are disposed at equal distances, and are used when the expansion of the walls is too great to admit of common rafters alone, which would be in danger of being bent or broken by the weight of the covering, for want of some intermediate support.

They are variously constructed, according to the width of the building, the contour of the roof, and the circumstances of the walling below.

Tie.—Any piece of timber connected at its extremities to two others acted upon by opposite pressures, which have a tendency from each other, or to extend the tie as a rope or chain.

Straining-piece.—A piece of timber connected at its extremities to two others acted upon by opposite forces, which tend to press them together. The straining-piece, by being placed between them, serves to keep them apart, and, further, acts as an abutment for the external pressure.

Hence a tie and a straining-piece act in a manner exactly opposite to each other—the one draws the ends of two pieces of timber *together*, the other keeps them *apart*. A rope, chain, or iron rod could be used for the tie; but the straining-piece, which has to bear end pressure, must be always stiff and inflexible.

Principal rafters, or, as they are sometimes called, "principals," are the two pieces of timber which form the sides of a truss; their lower ends being mortised into the end of the tie-beam, or resting in an iron shoe, whilst their upper ends abut on and support the head of the king-post.

Purlins.—Horizontal pieces of timber resting upon the principal rafters, and at right angles to them; they pass from truss to truss, and across these again are laid the

Common rafters, which are pieces of timber of a smaller section, placed at equal distances across the purlins, parallel to the principal rafters. They support the boarding or battens to which the slating is fixed.

The *tie-beam* is the horizontal piece of timber which forms the base of the triangle or other figure of which the truss may consist. As already mentioned, it receives the ends of the principal rafters, and is strapped up to the king or queen posts. The tie-beam answers a twofold purpose—viz., that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the room below. In some cases it is found desirable not to place a tie-beam at the foot of the rafters, but to use it as a connecting link higher up, something like the horizontal line in the letter A; in this case it is called a *collar-beam*.

King-post.—This is an upright piece of timber in the middle of the truss. Its upper end acts as a key-stone of an arch, against which the principals abut, and, being thus supported, the tie-beam is strapped or bolted up to its lower end; and thus not only is sagging or sinking prevented, but abutments are formed for struts, which give support to the principals in points between the tie-beam and the king-post.

Queen-posts.—Upright pieces of timber, framed above into the principals, and supported by a straining-piece or strut, whilst to their lower ends the tie-beam is bolted or banded up at points between the wall-plates and the king-post. Some trusses are constructed without king-posts; queen-posts only being used.

Struts are oblique straining-pieces, framed below into the king or queen posts, and above into the principal rafters, which are supported by them; or sometimes they have their upper ends framed into beams which are too long to support themselves without bending. They are often called *braces*.

Puncheons are short transverse pieces of timber fixed between two others for supporting them equally. They are sometimes called *studs*.

Straining-beam.—A piece of timber placed between the queen-posts at the upper ends, in order to withstand the thrust of the principal rafters.

Straining-sill.—A piece of timber placed between the lower ends of two queen-posts, upon the tie-beam, in order to withstand the force of the braces, which are acted upon by the force of the covering.

Camber-beams.—These are horizontal pieces of timber, made sloping from the middle towards the ends on the upper edge. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid. Their ends run three or four inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead. This is shown in Fig. 154 in the next page, which is the roof-truss of the chapel of the Royal Hospital at Greenwich, constructed by Mr. S. Wyatt.

Auxiliary rafters are pieces of timber framed in the same vertical plane with the principal rafters, under and parallel to them, for giving additional support when the extent of the building requires their introduction. They are sometimes called *principal braces*, and sometimes *cushion rafters*.

Joggles.—The joints at the meeting of struts with king-posts, queen-posts, or principal rafters, or at the meeting of the rafters with king and queen posts. The best form is that which is at right angles to the length of the struts.

Cocking, or Cogging.—The particular manner of fixing the tie-beams to the wall-plates. One method is by dovetailing; the other is by notching the under side of the tie-beam, and cutting the wall-plate in the reverse form to fit it.

Ridge-tree.—A piece of timber fixed in the vertex of a roof, where the common rafters meet on each side of it. The upper edge of it is higher than the rafters, for the purpose of fixing the lead which goes over it to cover the ends of the slates in the upper course.

Straps.—Thin pieces of iron running across the junction of two or more parts of a truss or frame of carpentry, branching out from the intersection in the direction of the several pieces. They ought always to be double—viz., one on each side of the timbers, and their ends strongly bolted to each of the pieces.

The uses of these various parts will be illustrated in the subsequent examples; but it must be understood that though every one of them *may* be found in the same roof, it is not necessary that any complete roof should have them all. The introduction of many of them depends on the distance of the walls, the contour of the roof, the partitions below, the quantity of head-room wanted in the garrets, etc.

Fig. 154 is the truss employed in the roof of the chapel of the Royal Hospital at Greenwich, already alluded to.

It is constructed with two queen-posts, B B, and has two struts, C C, from the foot of the queen-posts to the straining-beam, D, and which abut against a second straining-piece, E, underneath the first. The tie-beam, A, is also further suspended from the straining-beam by an iron rod, H, which answers the purpose of a king-post.

The trusses are seven feet clear apart. The platform is covered with lead, which is supported by horizontal beams 6 × 4 inches. The timbers of this are well disposed, and contain, perhaps, less wood than most roofs of the same dimensions.

The following are the scantlings of the various timbers, which are given to enable the student to work this example to a regular scale, and which should not be smaller than a quarter of an inch to the foot:—

	inches.
A, the tie-beam, 57 feet long, the span of the walls being 51 feet	14 × 12
B, queen-posts	9 × 12
C C′, braces or struts	9 × 7
D, straining-beam	10 × 7
E, straining-piece	6 × 7
F, principal rafters	10 × 7
G, camber-beam for platform	9 × 7
H, iron rod supporting tie-beam	2 × 2

It is scarcely necessary to remind the student that the tie-beam must be drawn first, then the queen-posts, the principal rafters, and the straining-beam; afterwards the struts and straining-piece; then follow the iron rod, the camber-beam, the purlins, and the covering.

Fig. 155 is the roof of St. Paul's, Covent Garden, London designed by Mr. Hardwick, and constructed by Mr. Wapshot, in the year 1796.

This roof, although of the same general construction as the chapel of the Royal Hospital at Greenwich, varies from it in several particulars.

There is a second pair of principals, H H, which are supported on the lower, F F, by studs, and the lower principals thus become only auxiliaries. The queen-posts, B B, are continued up to the principals, and a king-post, D, is carried from the apex to the straining-beam.

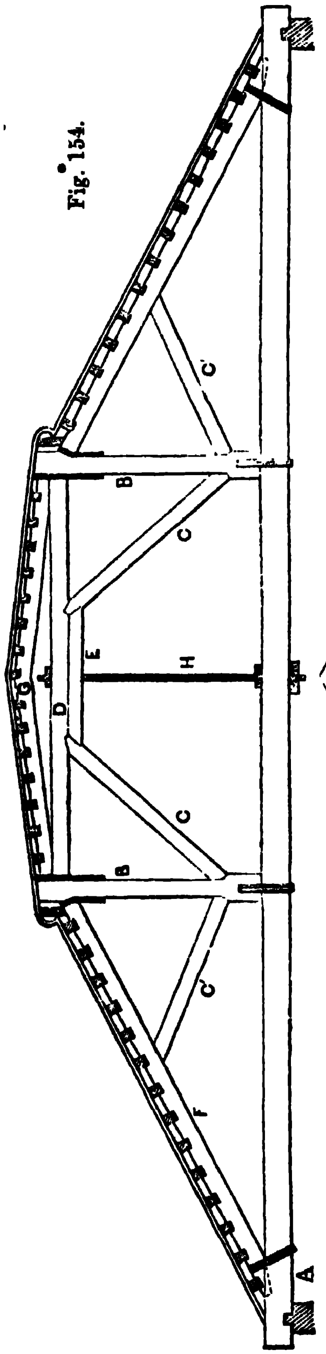


Fig. 154.

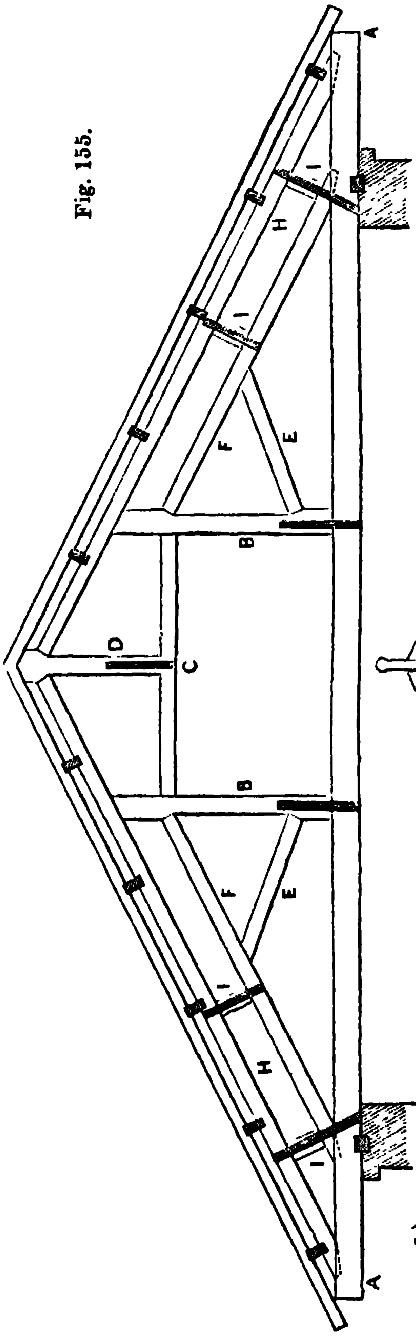


Fig. 155.

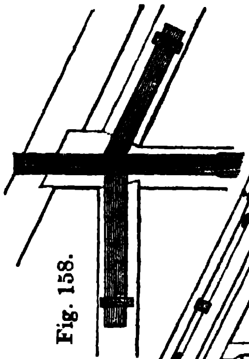


Fig. 158.

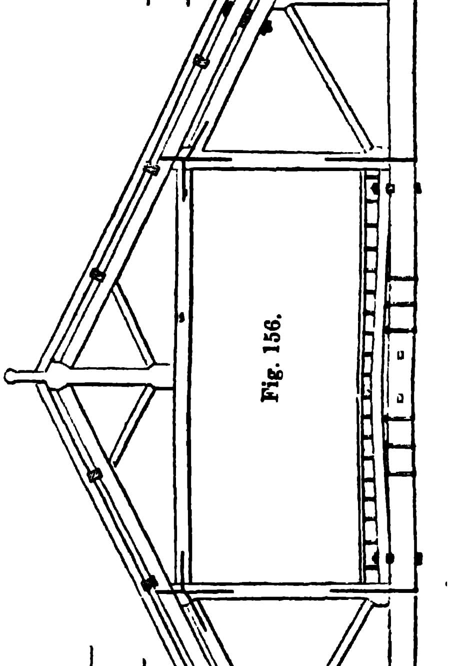


Fig. 156.

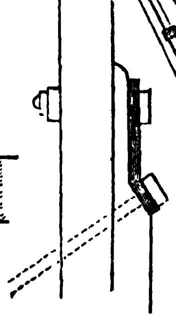


Fig. 157.

The following scantlings are given for the same reason as in the last case:—

	inches.
A, the tie-beam, spanning 50 feet 2 inches	16 × 12
B, queen-posts	9 × 8
C, straining-beam	10 × 8
D, king-post (14 inches at the joggle)	9 × 8
E, struts	9 × 8
F, auxiliary rafters at bottom	10 × 8½
H, principal rafters at bottom	10 × 8½
I, studs supporting the principals	8 × 8

It will be seen that this roof consists of an outer truss supported by an under one, the whole projecting seven feet beyond the walls.

Fig. 156 represents the present roof of Drury Lane Theatre, London. Here are both principals and auxiliary rafters, the tie-beam being suspended at two points from the former, and two from the latter, the two first queen-posts being the inner ones. These are kept apart by the straining-beam, against which they are pressed from the outer side by the auxiliary rafters. Struts are placed between the feet of the principal and the heads of the secondary queen-posts, and the bearing of the sub-rafters is still further reduced by a strut from the foot, and on the other side of the small queen-posts. The straining-beam is supported by a king-post, from the apex of the principals, which in their turn are supported by struts from the foot of the king-post, the other portion having a continuous bearing on the auxiliary rafters.

Fig. 157 shows how the timbers are joined and strapped at the top of the queen-posts, the whole being tightened up by iron wedges at the lower end of the iron strap, as already described in relation to king-posts.

Fig. 158 shows how the ends of tie-beams are strengthened by saddle-pieces, and how the principal and auxiliary rafters are inserted and bolted on to them. It will be observed that the heads of both the bolts pass through the same iron plate, which is bent at the oblique part of the saddle-piece, so that the head of the bolt may be at right angles to its length.

The method of drawing both the last figures is so precisely similar to the previous example, that no further instructions are necessary.

CIVIL ENGINEERING.—VII.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

CANALS.

The Cromford canal, constructed by Jessop, and completed in 1793, offers some points of interest to the engineer. The width at the top is 26 feet, but in the Ripley tunnel it is contracted to 9 feet at the surface of the water, and from thence to the crown of the arch the height is 8 feet. The tunnel is 2,966 yards long, and thirty-three shafts were sunk in its construction, some of which are 210 feet deep. The cost of the work averaged £7 per lineal yard. An aqueduct bridge, 200 yards long and 30 feet high, having a span of 80 feet, conveys the canal over the Derwent. The supply reservoir over the Ripley tunnel has an area of 50 acres; it is 12 feet deep, and contains 2,800 locksfull of water. The embankment of the reservoir is 200 yards long, 156 feet wide at the base, and 12 feet wide at the top. The cost of cutting and wheeling the clay to form the reservoir was 3¼d. per yard cube, and for gravel 4¼d. The entire canal cost £80,000. The boats navigating it are 80 feet long, 7 feet 2 inches wide, and 3 feet 4 inches deep. They draw 2½ feet of water when loaded with twenty-two tons, and only 9 inches when empty.

One of the more important canals in this country, before the development of the railway system, is the Ellesmere and Chester, connecting the Severn, Dee, and Mersey. The entire length is 103 miles. The most important feature of this canal is the aqueduct over the Dee at Pont Cysyllte. It is 125 feet high, the supporting pillars being 52 feet apart. The aqueduct itself consists of a cast-iron trough, 320 feet long, 20 feet wide, and 6 feet deep. The earthen embankment which meets the aqueduct attains a perpendicular height of 75 feet at the point of meeting, and the whole aqueduct, including the trough, is 1,007 feet long. The piers supporting the trough have their foundation in hard sandstone, and are 20 feet by 12 feet at bottom, tapering to 13 feet by 7½ feet at top. They are built solid for 70 feet from the foundation, and hollow, with 2 feet thickness of wall and one cross inner wall, for the remaining 50 feet. The water-way has a width of 11 feet 10 inches, the towing-path, which is 4 feet 8 inches wide, standing upon iron pillars over the water, by which simple and excellent arrangement there is no encroachment upon the water-way. The cast-iron plates forming the sides of the trough are strongly riveted to the bottom plates, and, wherever possible, ties and braces are introduced. The overhanging towing-path is itself a source of great strength to the side. In Fig. 13 we show a section of the cast-iron trough and towing-path. The entire trough is embraced within the four letters A B C D, the towing-path extending from A to E, supported by the pillar E E′; the cross-bar X acting as a brace or tie. The upright A A′ shows the protecting rail of the towing-path. The entire cost of the aqueduct and embankment was £47,018 6s. 7d., of which sum the iron-work cost rather over £17,000.

An important canal, the Gloucester and Berkeley, enables vessels of 400 tons burthen to pass up the Severn as far as Gloucester. It commences at Sharpness Point in that river, its entrance being protected from the south-west winds at that locality by a breakwater. The minimum depth of water throughout this canal is 18 feet.

The Grand Junction Canal, with its many ramifications, forms by far the most important system of internal navigation in this island. The total length of the system united by it is between 300 and 400 miles. The Blisworth tunnel, near Northampton, is an important piece of engineering connected with this canal. It is 3,080 yards long, 16½ feet wide, and has a depth of 7 feet from the water-line to the bottom of the inverted arch, and a height from the same level to the top of 11 feet. The side walls are segments of a circle of 20 feet radius, and the top arch one of 8 feet radius. The sides and top are two bricks thick, and the bottom 1½ bricks. The mortar was composed of 1 bushel of blue-lias lime to 3 of sand. At 6 inches below the water-line on each side of the tunnel are rails of fir, 5 inches square, to keep the barges off the walls. These are fixed by pieces of oak let into the brick-work, standing 9 inches off the wall. At every three yards a block of wood is fixed to the upper side of the rail, to act as a point for the bargemen to place their poles against. The soil through which the tunnel is cut is a hard blue clay, and cost £15 13s. per running yard. The cuttings forming the approaches to the tunnel cost 10½d. per yard cube at one end, and 11d. per yard cube at the other end. The headings for the tunnel cost 36s. per yard run at one end, and 42s. 6d. at the other end. The tunnel pits or shafts were nineteen in number, some being 60 feet deep, and cost, including steining, 30s. per yard run in depth. The entire cost of the Grand Junction Canal was two millions sterling. It is 90 miles long from Braunston to Brentford, where it enters the Thames, the width at bottom being 28 feet, at the surface of the water 42 feet, and the depth 4 feet 6 inches. The chambers of the locks are 80 feet long, and 14 feet 6 inches broad. There are eight supply-reservoirs for feeding the locks, each reservoir containing about 9,000 cubic feet of water, and capable in the aggregate of re-filling a single lock 17,000 times. It is worthy of notice that the reservoirs not being all upon the same level, and there not being an independent supply to each, the water is pumped by steam-power from the lower to the higher ones.

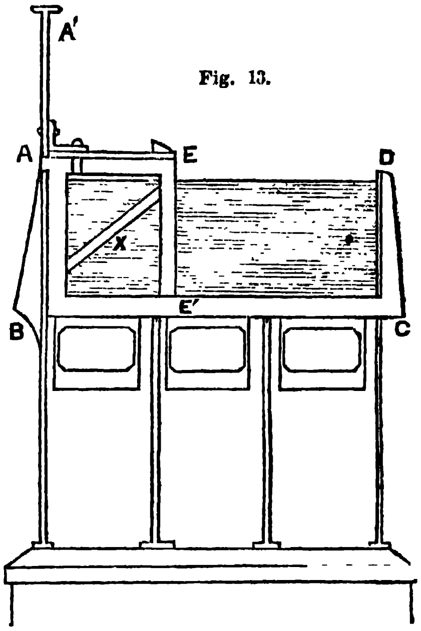


Fig. 13.

The Shropshire Canal, from Coalport to Donnington Wood, is the first canal on which the system of inclined planes was introduced. The originator was William Reynolds, of the Ketley iron works. The country over which this canal passes possesses a great scarcity of water, not sufficient to work locks. Hence the inclined planes were introduced. On the banks of the Severn is one of these planes 350 yards long, having a perpendicular height of 207 feet. A strong double line of rails is laid upon this plane to receive the boats with their carriages. The boats take a load of 5 tons, and when they arrive at the summit of the incline, pass by a level canal, 1¾ miles long, to the bottom of a second incline, 600 yards long and 126 feet high, where they enter a second level canal, which forms the summit of the system; after which the boats descend by other inclines to the other extremity.

The Thames and Medway Canal has a tunnel—now filled up and used as a railway—of 2¼ miles in length. This tunnel is driven through chalk of a very variable character, being in some places so soft as to crumble away before the miner, and in others so dense as to need blasting. The soil had in many spots to be supported by timber struts before the brickwork was built in: this varies from 14 to 18 inches. As the vaulting advanced, the space above the brick-work was filled in with chalk and lime mortar. The cutting of this canal, and the shafts connected with it, caused the water in the surrounding wells to sink so low that they had to be deepened to obtain a fresh supply; and when the salt water was admitted from the tide-ways, it pervaded the chalk and injured the quality of the water in these wells, the company being put to great expense in consequence of the damage. The width of water-way in the tunnel is 21 feet 6 inches at top, and 20 feet at bottom. The depth of water is 8 feet, the towing-path being 3 feet above the water. The greatest width of the tunnel is 30 feet.

The Harecastle tunnel, upon the Tetney Haven Navigation, was constructed by Brindley. It is 2,888 yards long, and being 9 feet wide, and only 12 feet high, it was necessary to propel the boats by employing a class of men called "leggers," who, lying upon their backs upon the freight, pushed against the sides and top with their feet. It occupied two hours to push a boat through in this manner. A second tunnel was constructed in 1824, by Telford, at a distance of 26 yards from Brindley's, and is a few yards longer than his. The width is 14 feet, and height 16 feet; 4 feet 9 inches of the width is occupied by the towing-path, but as it is supported over the water in the same manner as that in the aqueduct at Pont Cysyllte, the water-way is not interfered with. The mortar with which the bricks are set is impervious to water. Nearly 9,000,000 bricks were used in the construction of the tunnel, shafts, and culverts, and the total cost of the work, which scarcely occupied three years in completion, was £112,681.

Looking abroad, we find various schemes have been proposed, and in some instances carried out, for cutting canals through short necks of land, whereby thousands of miles of ocean navigation might be avoided. Amongst those only proposed is the Darien ship canal, intended to obviate the transhipment of freights passing between the Atlantic and Pacific Oceans, without the alternative of passing round Cape Horn. The first idea of such a scheme dates from 1771. Many surveys of the isthmus have been made from time to time, and particular attention paid to the northern portion, in consequence of the Lake of Nicaragua offering an apparently favourable feature in a line of navigation at this part. This extensive lake has an average depth of fifteen fathoms, and is separated from the Pacific sea-board by only 15 miles of land. This land, however, consists of a mountain ridge 615 feet above the Pacific, and 487 feet above the lake; and to cut through the ridge for a canal 30 feet deep and 50 feet wide—the dimensions necessary for a ship-canal—would necessitate the excavation and removal of nearly 5,000,000,000 cubic feet. Moreover, the ridge is volcanic, and it would be impossible to obtain a supply of water to feed a canal if, as an alternative to such a cutting as that alluded to, a portion of the ridge were overcome by locks, and the canal cut only through the upper portion. The lake is connected with the Atlantic by the river San Juan, whose length from the lake to its mouth is 119 miles. There are no cataracts or falls in the river, but a few rapids; it is at all times navigable for boats drawing from 3 to 4 feet of water, whilst the fall averages 1 foot per mile. It might therefore appear practicable to improve the navigation of the San Juan so as to make it available for a canal, but the apparently insuperable obstacles presented by the ridge upon the west coast makes this advantage of no avail. Another survey of this route was made in 1850-1, in which it was proposed to cut a canal 28¼ miles long, with 6 locks, on the Atlantic side of the lake, and to canalise the San Juan by means of 7 dams and 8 locks. The communication between the lake and Brito, on the Pacific, was to be effected by a canal 18⅓ miles long, with 14 locks. The summit of the ridge to be cut through on the Pacific side was found to be 46 feet above the lake, and the width of the ridge to be 8 miles. An artificial harbour would have been required at Brito. The whole length of the navigation would have been 194 miles, of which 56½ miles would have been by Lake Nicaragua, and the estimate for a canal 20 feet deep would have been £10,000,000 sterling. Had this canal been constructed, it was estimated that a vessel could have passed from the Atlantic to the Pacific in 77 hours. The objections to this route are so great and so numerous that the idea has been finally abandoned. Amongst the objections are the fearful insalubrity of the climate, owing to the swampy character of the banks of the San Juan. Upon this point it may be stated that Lord Nelson mentions that in 1779, when captain of the *Hinchinbrook*, he was engaged in an expedition to take the fort of San Juan, and the cities of Granada and Leon, and in one night, out of a complement of 200 men, 87 took to their beds, and not more than 10 of that crew survived, Nelson himself being carried ashore at Jamaica in almost a helpless state. The frequency of earthquakes, and the breaking out of fresh volcanoes, would also render any works undertaken very insecure in this district. Besides these serious objections, the mouth of the San Juan could never be made a suitable entrance for a ship-canal, as the sand-spit at its seaward face is always shifting; and, indeed, recent information is to the effect that the harbour is almost completely filled up, and the river has forced a channel for itself elsewhere.

Turning from a mere problem, we shall conclude the subject with a short reference to that most important, and now completed undertaking, the Suez Canal. This vast engineering work is made large and deep enough for a ship-canal, and enabling vessels to avoid the passage round the Cape of Good Hope, saves 3,000 miles on the voyage to India. It is 72 miles long, extending from Port Said, on the Mediterranean, to Suez, at the northern extremity of the Red Sea. Two distinct engineering works are comprised in the works undertaken by M. Lesseps—namely, the construction and maintenance of a broad and deep water channel on one level between the above named points, and also the maintenance of a supply of fresh water for the wants of the population congregated along the line of the canal, and especially at the two extremities. This latter undertaking was necessary in consequence of the avoidance of the Nile in any of its branches, and from the saline and arid character of the country through which the canal passes.

The construction of enormous jetties became necessary at Port Said, in order to protect the harbour, or canal entrance, from the action of the prevailing wind—the north-west. These jetties are formed of immense blocks of artificial stone, each weighing 20 tons, and were constructed on the spot. From this point the canal runs in a perfectly straight line for 40 miles to Lake Timseh, through which it passes, and which, previous to Lessep's operations, had been dried up for a lengthened period. The channel has throughout a minimum depth of 8 metres, and is in many parts 26 feet deep; being 190 feet wide at top, and 100 feet wide at bottom. The amount of soil excavated exceeds 147,000,000 cubic yards, and was performed by the continued action of powerful steam-dredging machines. The cost of excavation has exceeded £4,000,000. The entire undertaking displays an amount of indomitable perseverance and engineering talent rarely united in a single individual.

TECHNICAL DRAWING.—XXXIII.

DRAWING FOR MACHINISTS.

THE STEAM-ENGINE (*continued*)—GENERAL VIEW OF ENGINE.

FIGS. 383 and 339.—The side and end elevation show all the before-named details, and also the bed and fly-wheel in their proper places as fitted together and ready to work. It will be easy to follow each detail into its place. There are only two elevations of the engine-bed; its thickness would be ⅝ inch at the sides and ¾ inch at the top, which is planed all over and made smooth. This engine is not an example of the cheapest form of construction, but is very strong and durable, and suited for high pressures. It is also a good specimen of suitable beauty and fitness of form for such work.

This set of drawings illustrates the proper system for sending plans from the drawing-office into the workshop: the details are given in such a manner that a good workman would find no difficulty in understanding them, and making the engine without further instructions. It is very desirable to put dimensions for all the principal parts where drawings are not made full size; but for such an engine as this one, many of the details might be made full size, and the rest to a large scale or half size. Figures upon a drawing save workmen much time and conduce to accuracy; very few are given in these details, for the sake of avoiding confusion in the lines.

In making drawings the lines for dimensions should be drawn with red or blue ink.

FOUR-INCH SAFETY-VALVE (*scale, three inches to one foot*).

When steam is raised in a closed boiler its pressure gradually accumulates, and would at last burst the boiler unless means were provided for its escape. Safety-valves are arranged for this purpose, and their general principle is that of placing a known weight upon a valve, so that the steam shall lift it and escape whenever its pressure becomes greater than is desired.

Fig. 340 is the plan, and Fig. 341 the side view, partly in section to show details of construction. At the extreme left side of the sheet is a fulcrum or fixed centre for the safety-valve lever, and at the opposite side a heavy weight. Close to the fulcrum is a pointed link, which presses upon a brass valve. As the distance between the fulcrum and valve-centre is 3½ inches, and between the fulcrum and weight (when at the end of lever) is 28 inches, every pound will press with eight times the force—viz., 8 pounds—on the valve by the well-known principle of a lever. Knowing the area against which steam presses, it is not difficult to calculate the resistance offered by the weight and lever, so that any desired pressure of steam may be enabled to lift the valve and escape. These valves and seats are made of gun-metal, an alloy of copper and tin, and the bearing surfaces are ground together so as to be steam-tight. A small groove is turned in the conical seat, and a piece of string inserted before it is driven into position, so as to prevent any leakage. The cup form of the cast-iron pipe is adopted so as to cause any escape of steam to rise upwards, instead of spreading out like a flat disc.

Figs. 342 and 343 represent the wrought-iron tongue which is cast into the valve-weight, and forms a means of suspending it from the lever. The roughened corners are intended to give a greater hold to the cast iron when it is poured over the tongue in a melted state.

A spring may be used instead of the weight, and in many positions, such as on locomotive engines, it has been found more convenient.

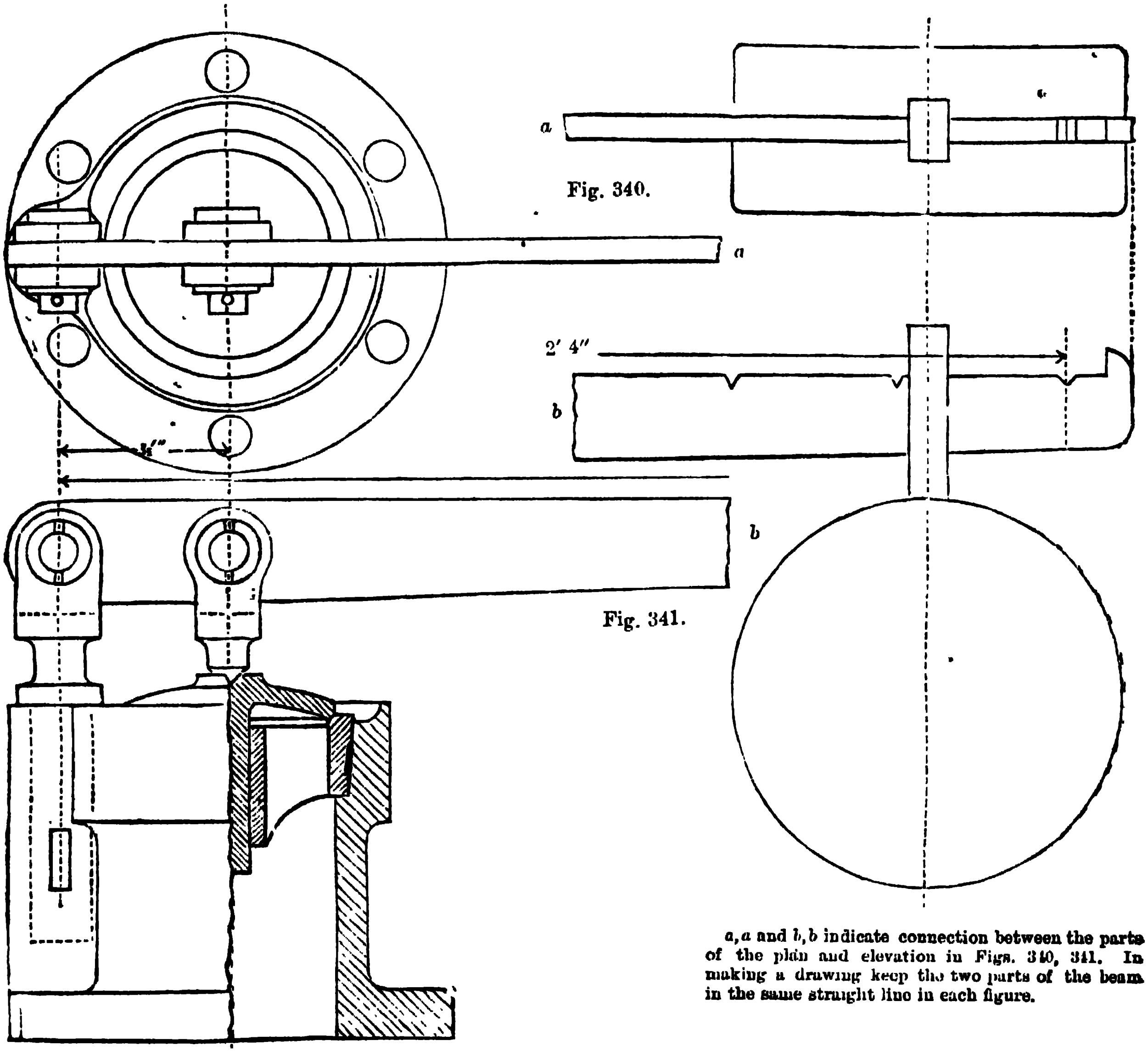


Fig. 340.

Fig. 341.

a, a and *b, b* indicate connection between the parts of the plan and elevation in Figs. 340, 341. In making a drawing keep the two parts of the beam in the same straight line in each figure.

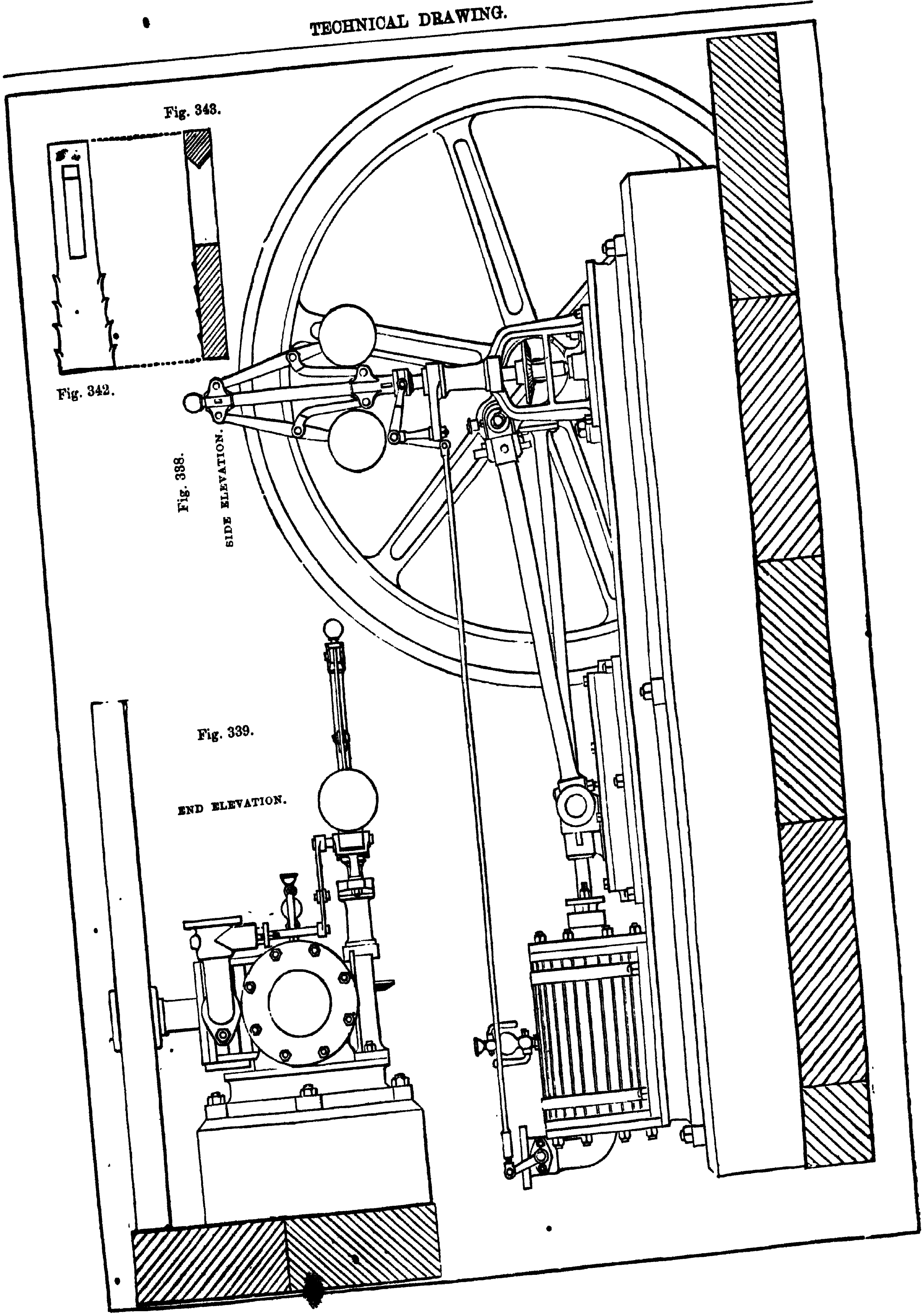


Fig. 343.

Fig. 342.

Fig. 338.

SIDE ELEVATION.

Fig. 339.

END ELEVATION.

NOTABLE INVENTIONS AND INVENTORS.

XII.—THE COTTON MANUFACTURE (*concluded*).

BY JOHN TIMBS.

We must now return to Hargreaves' frame, in which a number of previously prepared rovings were drawn out to a greater fineness and twisted into yarn. Now Arkwright's invention prepared the rovings and spun the yarn; Hargreaves' could do the latter only. The former was best adapted for producing firm warp yarn; the latter for spinning the finer kinds used as weft. The union of the principles of both was necessary to perfect the art of spinning. The rollers of Arkwright and the motion from the spindles of Hargreaves are united in the mule of Crompton, which he invented in 1797, and, after many unsuccessful attempts, made self-acting; so that one spinner can make 800, 1,000, or even 2,000 threads at once. "The rovings," says Mr. Syme, "part the rough rollers, which turn for some time, and then stop. The spindles are placed on a carriage, which moves from the rollers after they have ceased to turn and draw out the thread; the spindles revolve, the requisite twist is communicated to the fibres, and the thread thus spun is then wound on the bobbins as the carriage advances towards the rollers." As soon as the whole of these processes are performed, the mule disengages itself from those portions of the machine which have been used to propel it, and the attendant returns it again to the carriage, to perform its work afresh. To give an idea of the value of this invention: while the water-frame is capable of spinning a pound of cotton to the length of nineteen miles, or forty hanks, the mule has not met with any limit short of 950 miles to the pound of cotton, or 2,000 hanks.

Samuel Crompton was born in 1753, at Firwood, near Bolton, his parents occupying a farm, and, as was the custom of that time, employing their leisure hours in carding, spinning, and weaving. They removed, when Samuel was five years old, to a portion of the neighbouring old mansion called "The Hall in the Wood." The boy was well educated in Bolton, but "his little legs became accustomed to the loom almost as soon as they were long enough to touch the treadles." When only sixteen years of age he spun on one of Hargreaves' jennies, with eight spindles, the yarn of which he afterwards wove into quilting, and thus he was occupied for the five following years.

At his solitary loom, in the Old Hall, he became prematurely a thinker, and cultivated a taste for music, which led to the first trial of his mechanical skill in making a violin. He was master of Hargreaves' invention, the jenny, and he was personally known to Arkwright, whose reputation as an inventor now rang through Lancashire. In the dining-hall of the old mansion, Crompton, in 1774, commenced the construction of his spinning machine, which for many years was known as "the Hall in the Wood Wheel." It took him five entire years to mature his improvement, working entirely alone, and he tells us that he succeeded at the expense of every shilling he had in the world; all this labour being in addition to his every-day work. He toiled late and early; he devoted every shilling he could spare to the purchase of the requisite tools; and, aided by his clasp-knife, he at length triumphed. His machine was first called "the Muslin Wheel," because it was available for yarn for making muslins, and it got the name of the "Mule," from its partaking of the two leading features of Arkwright's machine and Hargreaves' spinning jenny; but it is certain that when Crompton constructed his machine he knew nothing of Arkwright's discovery.

As soon as Crompton had completed his first mule, in the year 1779, to save it from destruction by the Blackburn spinners and weavers, he took it to pieces, and concealed it in a loft at the Old Hall. Here it remained for many weeks, but in the same year the wheel was re-constructed, and out of its first earnings Crompton bought himself a silver watch. In 1780 he married. Assisted by his wife, he industriously spun at the Hall, his yarn producing higher counts and an improved quality, for which he readily obtained his own prices, but he could not satisfy one-hundredth part of the demand. The Old Hall was now besieged not only by purchasers, but others to get at the mystery of the wonderful new wheel. Admission was denied, when many, who climbed up to the windows, were blocked out by a screen; but one inquisitive seeker concealed himself for some days in a loft, and watched Crompton at work by means of a gimlet-hole pierced through the ceiling; and thither Arkwright travelled sixty miles to endeavour to discover the secret of the new wheel, which all but eclipsed his water-frame. But Crompton found it impossible to retain the secret of his machine; he had no patent, or the means of purchasing one; and, rather than destroy the whole, he gave it to the public, when some "manufacturing friends" promised to raise for him £60; yet the list of half-guinea subscribers of this paltry amount contains," says Mr. Gilbert French, "the names of many Bolton firms of great wealth and eminence as mule-spinners, whose colossal fortunes may have said to have been based upon this singularly small investment." In the five following years the mule was generally employed for fine spinning throughout the manufacturing districts.

Before 1785, Crompton removed to a farm-house near Bolton; and there, besides farming, he worked secretly at his machine in the upper storey of his house. Curious visitors still came, and among them was Mr. (afterwards the first Sir Robert) Peel, who attempted to get at the mule in Crompton's absence, but was defeated. He subsequently offered the inventor a lucrative situation, and even a partnership in his establishment, both which Crompton declined to accept. Crompton next, with £500 subscribed for him at Manchester, rented a factory storey at Bolton, and there had two mules, with the *power* to turn the machinery. He then submitted his machine to the Royal Society and the Society of Arts, but by neither was it entertained. The public had got it, and that was enough. Crompton then visited the manufacturing districts, where he found the number of his mule spindles in use to be 4,600,000, spinning 40,000,000 pounds of cotton wool in a year; that 70,000 persons were engaged in spinning, and 150,000 more in weaving the yarn so spun; and that a population of full half a million derived their daily bread from the machinery his skill had devised. Our inventor then petitioned Parliament for remuneration, and Mr. Perceval, the Chancellor of the Exchequer,* was ready to propose a handsome grant of money, when it was frustrated in a shocking manner. On May 11, 1812, Crompton was standing in the lobby of the House of Commons, conversing with Sir Robert Peel and Mr. Blackburne, when they were joined by the Chancellor of the Exchequer, who remarked, "You will be glad to know that I mean to propose £20,000 for Crompton; do you think it will be satisfactory?" Crompton retired, and did not hear the reply. He was scarcely out of sight, when the madman Bellingham came up, and shot Mr. Perceval dead. By this frightful catastrophe Crompton lost £15,000. Six weeks intervened before his case could be brought before Parliament, and then Lord Stanley moved that he be awarded £5,000, which the House voted without opposition. No reason was given for the reduction of Mr. Perceval's proposition: the smaller grant was inadequate, whether measured by the intrinsic value of Crompton's services, or by the rate of Parliamentary rewards to other inventors. When he returned to Bolton with £5,000, instead of a great fortune, he heard the bitterest reproaches from his family. With the above sum Crompton entered into manufacturing speculations with his sons, but unsuccessfully; and as he advanced in years, some of his friends subscribed, and purchased him an annuity of £63. A second application in his behalf was made to Parliament, but failed. This must have been very mortifying to Crompton, who was one of the most sensitive as well as honourable of men, and who is known to have declared to one of his most stedfast supporters in Parliament, "I only request that the case may have a fair and candid hearing, and be dealt with according to its merits."

Worn out with cares and disappointments, Crompton died at Bolton on the 26th of June, 1827, at the age of seventy-four, and was followed to the grave by a host of Bolton worthies. A statue of Crompton, in bronze, by Calder Marshall, was erected in the market-place at Bolton, in 1862; though to be treated with respect after death is but a poor recompense for being neglected while we are living. "Justice exacts," says Samuel Johnson, "that those by whom we are most benefited should be most honoured."

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* Mr. Perceval is spoken of here as "Chancellor of the Exchequer," and rightly enough. It must, however, be remembered that he was Premier as well, and the head of the Administration from October 30, 1809, to May 11, 1812. Both offices were also held conjointly by Pitt, Canning, and Peel.

Mr. French, in his "Life and Times of Samuel Crompton," with graceful earnestness, has vindicated his claim and character, and thus rescued him from neglect. It may safely be asserted that Crompton's mule is the fulcrum which sustains that mighty lever, the cotton trade, the most valuable and most powerful of our national resources. As the jenny is now almost disused, and all the finer yarns are spun exclusively upon the mule, its importance and value continue to increase. The principle of Crompton's invention has remained unchanged; while modifications, improvements, and auxiliaries have increased its productive power a hundredfold. Meanwhile, the results of Crompton's genius have been practically commemorated upon the site of his invention. Near the Hall in the Wood rises an octagonal chimney-shaft 366 feet in height, in connection with the steam-engines and furnaces in a huge factory, where some thousands of men and boys are employed in making mule-spinning machinery, and in the production of thousands of mule-spindles. The old Hall has become the veritable centre of the existing cotton manufacturing district. "Could we," says Mr. French, "tie a cord, twenty miles in length, to the top of the tall chimney that marks the spot, and sweep it round the country, the circle then formed would embrace the populous towns and teeming villages engaged in spinning and weaving cotton. They radiate from that centre with compass-like regularity; Manchester, Preston, Oldham, and Blackburn being the cardinal points."

The triumphs of the combination here described were not confined to spinning. It had been repeatedly but unsuccessfully attempted to weave cloth by machinery before. It was effected by a singular accident. Edmund Cartwright, a brother of Major Cartwright, the politician, had been educated for the Church in the University of Oxford, had written and published several poems, and had reached his fortieth year before he had given any attention to mathematics. Mr. Cartwright, in 1784, being at Matlock, in the company of some gentlemen of Manchester, maintained the practicability of inventing a machine to weave the vast additional quantity of cotton spun by Arkwright's machinery. It occurred to Cartwright that, as in plain weaving, according to the conception he then had of the business, there could be only three movements to follow each other in succession, and little difficulty in producing and repeating them. He then had constructed upon this principle a machine, and getting a weaver to put in the warp, to his great delight, a piece of cloth was the result. The warp was laid perpendicularly: the reed fell with the force of at least half a hundredweight, and the springs which threw the shuttle were strong enough to have thrown a Congreve rocket. His machine was rude and awkward, for his own loom was the first he had ever seen. It was opposed both by prejudiced manufacturers and their workmen, and a mill containing 500 of his looms was wilfully burnt down. He, nevertheless, persevered, but after taking out several patents, and spending upwards of £40,000, he relinquished all hope of accomplishing his object. In 1809, however, Parliament voted him £10,000 for "the good service he had rendered the public in his invention of weaving." He died in 1823, in the eighty-first year of his age.

Power-looms remained unprofitable until it was discovered, in 1803, that the warp might be dressed before being put into the loom, by a machine consisting of eight rollers, four at each end of a frame. These rollers are brought from the warping frame, and the yarn passes between two rollers, the lower one of which dips into a reservoir of thin paste, and thus transfers a coating of starch to the cotton. The yarns afterwards pass over and under brushes for rubbing into the fibres, then over a heated copper box to dry them, and they are ultimately coiled round the warp beam of the loom. The construction of the machine and method of dressing have since been improved, and cloth is now woven, by the help of steam, with wonderful rapidity and extent. A steam-engine of 40 or 60 horse-power gives motion to thousands of rollers, spindles, and bobbins for spinning yarn, and works four or five hundred looms besides. This gigantic spinner and weaver needs very little assistance from man. It undertakes and faithfully discharges all the heavy work of putting shafts, wheels, and pulleys in motion; of throwing the shuttle, working the treadles, driving home the weft, and turning round the warp and cloth-beams. One man may now do as much work as two or three hundred men ninety years ago. Power-looms are among the most extraordinary machines in a factory. The operations of one of these looms being minuted with a watch, have been seen to weave seventy-two square inches of cloth in a minute, without any human being attending to it.

The substitution of machinery in place of hand-labour in spinning and weaving has been productive of the most beneficial consequences, since the inventions of Arkwright and Watt were made. At first, the various operations of beating, carding, roving, and spinning were household operations; but progressively, with a view to economy of time and quickness, they led to the building of factories; and the concentration of them under one roof, with a propelling power of water or steam, gave a united and combined action to all the processes, which caused them to be carried on with the precision of clockwork. Nor has improvement been obtained in one branch of industry, but in all. Really good small steam-engines and mill-gearing could not be manufactured when mechanical power was first introduced. Now, in place of heavy shafts of wood, and cast-iron huge wheels and pulleys, we have light wrought-iron rods, smaller wheels, quintupled velocities, and diminished friction.

In a cotton-mill the most striking actions of machinery are those which involve not only swift, irresistible motion, but also transformation of the materials on which the moving force is exerted. "In the basement storey revolves an immense steam-engine, unresting and unhasting as a star, in its stately, orderly movements. It stretches its strong iron arms in every direction throughout the building; and into whatever chamber you enter, as you climb stair after stair, you find its million hands in motion, and its fingers, which are as skilful as they are nimble, busy at work. They pick cotton, and cleanse it, card it, rove it, spin it, dye it, and weave it. They will work any pattern you select, and in as many colours as you choose, and do all with celerity, dexterity, and unexhausted energy and skill; and with the speed of racehorses transform a raw material, originally as cheap as thistle-down, into endless useful and beautiful fabrics." (Professor George Wilson.)

Mr. Tuffnell states that, in the fine spinning-mills, he has seen a pound of cotton stretched to the incredible length of 294,000 yards, or 167 miles, and then sold for twenty-five guineas, the original cost of it having been 3s. 8d.

But what a concentration of mental work is requisite to produce these wonderful machines! In a factory, into which the cotton is taken in a raw state, and is brought out as cloth, there is not one of the numerous machines through which it has to pass, including the steam-engine, which moves them all, that does not seem to demand the utmost stretch of human ingenuity to bring it to its present state—not one that does not condense in its formation the result of at least a hundred patents, or that has not required in its invention the united efforts of at least a hundred minds.

We conclude with a few interesting statistics. Cotton-growing in the United States began with the century, and rose from 400,000 bales in 1820 to 5,000,000 bales in 1859 and 1861, the two most productive years. The price in the same period fell from 50 cents to 10 cents a pound. Since the close of the civil war cotton culture has rapidly revived, and it is estimated that the crop of the past season will reach 4,000,000 bales, a quantity only surpassed in 1859 and 1861. The war between France and Germany has, however, operated disastrously on prices, and cotton that was selling at 25 cents a pound a year ago, is to-day quoted at less than 15 cents.

In 1840, Mr. Buxton stated there were employed in our cotton manufacture about £2,000,000 of fixed and £20,000,000 of floating capital invested. The total yearly produce of the manufacture amounted to £40,000,000. 1,500,000 persons then earned their bread by it.

The Board of Trade accounts state that the import of raw cotton into the United Kingdom in the first quarter of the year 1871 reached the large amount of 5,318,511 cwt., stated to be of the value of £18,738,015. The quantity is more than double that of the corresponding period of either of the two preceding years, but the price shows a very great decline. Above half a million cwt. came to us from India, and above half a million from Egypt; the quantity sent in from the United States was not less than 3,949,190 cwt. The exports from this country of imported cotton in the three months already named have exceeded a million cwt.

APPLIED MECHANICS.—XIII.

BY ROBERT STAWELL BALL, M.A.,

Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.

THE DRILLING MACHINE.

THE drilling machine is of the utmost use in the workshop. Holes are constantly required to be produced, either for the purpose of receiving bolts, or for numerous other purposes. Many different forms of drill are in common use. We have selected for description in the present lesson one of the most ingenious which has been invented. This drill is shown in the illustration below (Fig. 1).

For drilling, the tool must receive two distinct motions—one that of rotation, the other that of advance parallel to its axis; the work being held steadily. In this the drill may be contrasted with the turning lathe and the planing machine. In both of these the work is moved, while the tool is also moved. Having to give the two motions to the tool of the drilling-machine, instead of being able to give one of them to the work, makes the drilling machine a little more complicated than either of the machines already described, as we have to provide for the two motions simultaneously.

S represents the point of the drill; the work, which is not shown, is supported upon a table underneath the drill, which can be moved in two directions, so as to bring the work beneath the drill in the proper position. The drill is fastened to a screw, T; this screw works in the nut E. The toothed wheel X is fastened upon the nut E, while the wheel Y is fastened upon the screw. A, B, and C are three pulleys. A is an idle pulley; B is keyed upon the shaft that carries N; and M and C are attached together. It will be noticed that M and N are not of the same size, nor are X and Y. We shall let m, n, x, y represent the numbers of teeth in the four wheels, M, N, X, Y. When the band is upon A the machine is at rest; when the band is upon B, N and Y are turned round, and the drill is brought down to its work by being screwed out of its nut. When the band is upon C, the nut E is made to revolve, and the screw is drawn up into its nut, and raised from the work. But when the band is upon both B and C the drill revolves and the nut revolves; but the drill screws out of the nut faster than the revolution of the nut brings it back, and thus a slow motion of advance is combined with the rotation of the drill.

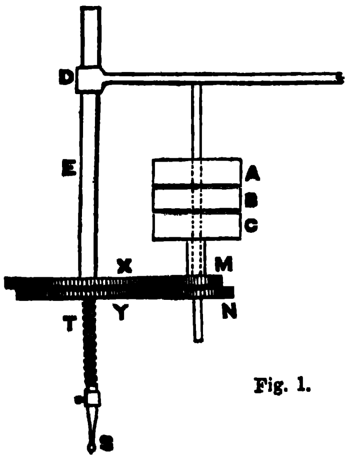


Fig. 1.

Let k represent the number of threads in the inch upon the screw T.

For one revolution of the pulley B, the screw will have made

$$\frac{}{y} \text{ revolutions,}$$

and will therefore have been depressed by

$$\frac{n}{y} \times \frac{1}{k} \text{ inches;}$$

but on account of the revolution of the pulley C, the nut E has made

$$\frac{m}{x} \text{ revolutions,}$$

and has therefore raised the screw by

$$\frac{m}{x} \times \frac{1}{k} \text{ inches.}$$

Hence the real advance of the screw being the difference between the amount by which it is raised and lowered is

$$\left(\frac{n}{y} - \frac{m}{x}\right)\frac{1}{k}.$$

This is the amount by which the drill is lowered when it has made

$$\frac{n}{y} \text{ revolutions.}$$

Therefore, the amount by which the drill descends for one revolution is

$$\left(\frac{n}{y} - \frac{m}{x}\right)\frac{1}{k} \times \frac{y}{n} = \left(1 - \frac{my}{xn}\right)\frac{1}{k}.$$

This quantity can have any value by proper selection of the wheels, the only condition to be attended to in the choice of wheels is that

$$x + m = n + y,$$

because if this equation were not satisfied, the two pair of wheels could not be adjusted to gear simultaneously.

To illustrate these formulæ by an example, we shall suppose that the screw has three threads to the inch; that is, $k = 3$; and that $m = 40$, $x = 120$, $n = 50$, $y = 110$. These numbers satisfy the relation—

$$x + m = n + y.$$

The expression $\left(1 - \frac{my}{xn}\right)\frac{1}{k}$ becomes

$$\left(1 - \frac{40 \,.\, 110}{120 \,.\, 50}\right)\frac{1}{3} = \frac{1}{11 \cdot 2}.$$

Therefore, for each revolution of the drill its point will advance about the eleventh part of an inch. In fact, the drill is much the same as if it were simply attached to a screw containing eleven threads to the inch, and rotating on its nut.

This arrangement can be made to produce a very slow advance of the drill. Thus, suppose $m = 40$, $x = 120$, $n = 41$, $y = 119$, the advance is

$$\left(1 - \frac{40 \cdot 119}{41 \cdot 120}\right)\frac{1}{3} = \frac{1}{92}.$$

Thus the drill must perform 92 revolutions before it will have advanced one inch.

MACHINERY USED IN THE MANUFACTURE OF SUGAR.

The preparation of sugar before the product is brought into the form in which we are familiar with it, involves two distinct branches of manufacture. One of these, the preparation of raw sugar, is conducted at the place where the sugar is grown; the other, called sugar refining, is usually performed at home.

It is not within our province to give in the present paper a description of the technical details of the manufacture, except so far as may be necessary to enable the action of the machines used to be understood; many of the processes come more properly within the province of the chemist than of the mechanic.

There are two important stages in the manufacture in which machinery is used. The first is in the expression of the raw juice from the cane, and the second is the separation of the crystals of refined sugar from the liquor in which they are contained. There are, of course, multitudes of minor mechanical contrivances for hoisting, pumping, etc., used in various parts of the manufacture; but as these are not peculiar to this branch of the mechanical arts, we shall not further allude to them in this lesson.

We shall describe the machinery used in these two different processes.

The juice from which the sugar is extracted is expressed by pressure from the sugar-cane. The cane is a long stalk about two inches in diameter; the outside is hard, the inside is soft, and contains the juice which it is the object of the cane-mill to extract.

Fig. 2 represents in a diagrammatic manner the principle of the cane-mill which is most usually employed. A, B, C are three rollers with flanges at their extremities to prevent the canes from escaping; they are made of cast iron. In some of the larger works these rollers are very massive, reaching the length of six feet, and a diameter of thirty inches; the roller C is sometimes fluted longitudinally, so as to draw in the cane with certainty; but this is, however, not necessary, and as the cane is much crushed and injured by the fluting, the roller is frequently smooth. The three rollers are made to revolve together, by means of toothed wheels, not shown in the figure, and the whole is worked either by a steam-engine, or by the power of wind or water.

D is a flat table, upon which the canes are strewed to be delivered to the first pair of rollers, A, C. These rollers are about a quarter of an inch distant from each other. The space can be regulated by means of screws. The cane is thoroughly crushed between the first pair of rollers, A and C, and rendered into a fit condition to receive the extreme pressure which the compressed mass receives between the rollers B and C.

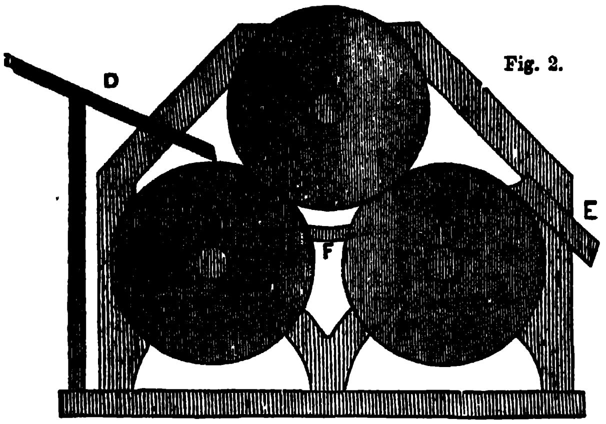


Fig. 2.

At F is a plate upon which the crushed canes, after passing the first pair of rollers, are deflected so as to pass between the rollers B and C. These rollers are so close together that a sheet of ordinary writing-paper would only just pass between them. The canes submitted to this great pressure yield up the sweet juice contained in their cells; this juice trickles from the rollers into a trough placed to receive it, whence it is conveyed to vessels in which the process of preparing the raw sugar is commenced.

The rollers being so close together are more or less liable to jam, when an unusual quantity of cane is delivered to them. Such a sudden cessation of motion in so heavy a piece of machinery would be productive of injury, if not to the rollers themselves, at all events to the gearing by which their motion is sustained. Different methods are adopted to evade this difficulty. In some cases the rollers are turned by the aid of what are called friction wheels. The nature of friction wheels will understood from the annexed cut (Fig. 3).

Instead of the wheels being toothed on the circumference, there are a series of ridges which fit into corresponding grooves. When the wheels are pressed together, the friction causes the revolution of one of the wheels to make the other wheel revolve. If, however, the wheel which is being driven be stopped, or experience some very large resistance, no accident occurs, as the driving wheel merely slips upon the other without turning it round. All that is necessary is that the friction between the two wheels shall be a little greater than the force necessary for driving the cane-mill in its ordinary condition.

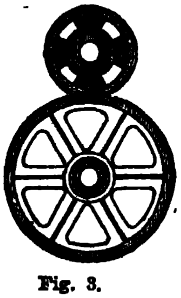


Fig. 3.

Another method of avoiding accident to the machinery by the jamming of the rollers depends upon a different principle. The rollers are usually adjusted at the proper distance by screws, but it is evident that, provided one of the rollers could be pressed towards the other with sufficient force, the screws may be dispensed with. This is the principle of the second method referred to. The roller B (Fig. 2) is urged towards the roller C by severe pressure produced by levers and weights: when an undue strain comes upon the rollers, the roller B is pushed away from C, and the obstraction is enabled to pass.

It is found by experience that a greater per-centage of juice is extracted from the cane when the rollers move slowly, at about the rate of two or three revolutions per minute, than when they have a higher velocity. The canes, after the juice has been expressed, are used as fuel for supplying the fires when heat is required in the subsequent treatment of the juice.

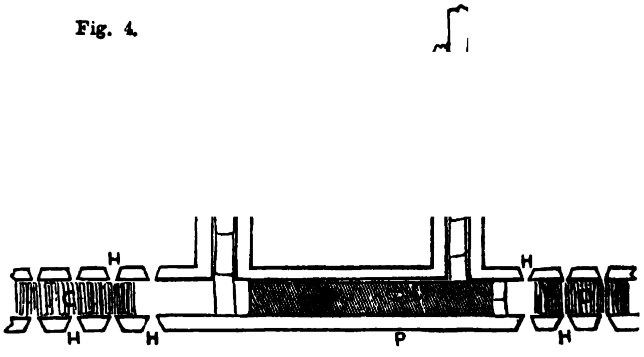
A considerable per-centage of the juice remains in the canes after having been submitted to the cane-mill. This juice, and of course the sugar contained in it, is lost. A cane-mill has been proposed by Mr. Bessemer, with the object of more completely extracting the juice from the cane than is possible in any mill in which the action is conducted by rolling. A diagram of the principle of this mill is shown in Fig. 4.

P is a solid plunger, which oscillates to and fro in a tube. The plunger is driven by a crank, and receives considerable power with the aid of the inertia of a fly-wheel. The canes are supplied to the mill by the vertical tubes A and B. The plunger, in the position shown in the figure, is about to move towards D; in its passage it cuts off the end of the cane in the tube B, and compresses the segment thus cut off against the mass of bruised cane D. The juice which flows from the cane escapes through the holes H, H in the tube. These holes are conical, with the narrow end outside to avoid clogging. On the return of the plunger to C a segment from the end of the cane in A is cut off, and has its juice expressed. A new length of cane in B descends into the tube to be ready for a fresh operation.

Thus two canes are supplied to each tube at the same time, and several plungers and tubes can be worked by the same engine. It is believed that by this process the juice is more completely expressed than by rolling. Not only is sugar saved, but the compressed canes are drier, and therefore in a fitter condition for fuel, and this is a very important consideration in many of the colonies, where fuel is scarce and expensive.

The treatment of the juice by evaporation, necessary for the extraction of the raw sugar, does not involve any very special machinery. We shall therefore pass on to the mechanical appliances made use of in the process of refining the sugar.

Fig. 4.



The most interesting part of the process of sugar refining, from a mechanical point of view, is the application of centrifugal force to the separation of the crystals of sugar from the liquid in which they are contained. After the syrup has been concentrated in the vacuum pan crystals form throughout the mass, which becomes something of the consistence of mortar, and is of a brownish colour. When intended for making sugar-loaves this mass is placed in a mould of the proper form, and the liquid portion trickling away leaves the loaf in the form in which we are familiar with it; but when the crystalline soft sugar is to be made, centrifugal force comes into play. We shall calculate the magnitude of this force, referring the reader to the lessons in Mechanics for the demonstration of the theorems which will be used.

If a point be moving round in a circle, of which the radius is R, and T the time of revolution, the magnitude of the centrifugal force is

$$4\frac{\pi^2 R}{T^2}.$$

We shall suppose that R equals two feet, and that the particle makes ten revolutions per second; the magnitude of the force is therefore—

$$4 \times \left(\frac{22}{7}\right)^2 \times 2 \times 100.$$

This quantity reduces to 7884. The force of gravity is 32, therefore the ratio of the centrifugal force to gravity is 7884 ÷ 32. Hence the centrifugal force is about 246 times greater than the force of gravity.

We learn from this example how great is the force which can be produced to expel the water from between the crystals of sugar. Each particle of water is urged towards the exterior with a force equal to 246 times the weight of the particle of water.

The apparatus consists of a large iron cylinder, the sides of which are perforated. This cylinder is mounted upon a vertical spindle, and by means of wheelwork this cylinder is capable of receiving a rapid motion of revolution. Into this cylinder a charge of the mixture of the crystals with the water is introduced. When the motion commences the centrifugal force makes the contents of the vessel fly to the circumference, the liquid passes through the holes in the sides of the vessel, and the crystals of sugar form into a layer round the sides several inches thick. When the water has been expelled a little clear syrup is introduced into the vessel; this syrup passes through the sugar, and carries with it the last traces of the coloured liquid. When the motion ceases the sugar is ready for market.

The peculiar advantage of centrifugal force for this process is that each atom of water is expelled by a force which acts upon itself directly, and is not transmitted by the pressure of the surrounding particles. For example, suppose the sugar-cane subjected to pressure in a hydraulic press, or in some other machine adapted for the purpose; the particles of sugar on the exterior would be crushed, but the pressure would only be imperfectly transmitted to the interior. In fact, unless the crystals were so compressed together that all the interstices had disappeared, the water would still remain in the mass. If the compression could be carried to such an extent that this should be attained, it is manifest that the crystals would be crushed and disfigured. But with centrifugal force the action is quite different. When the crystals are packed as close together as possible without injury to their form, numerous interstices are left; from these the water flies because it is itself acted upon by the force of its own inertia.

It is manifest that this useful application of centrifugal force is capable of more extended utility than the single example we have given. Drying machines for cloths which are in process of bleaching depend on the same principle. The liquid flies from the interstices of the cloth in the same way as it does from those of the sugar.

PRACTICAL APPLICATION OF THE FINE ARTS.—I.

THE ART OF GLASS-PAINTING.

BY P. H. DELAMOTTE,

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I.—INTRODUCTORY.

THE discovery of glass, like that of many other most useful and important inventions, is wrapped in obscurity. Not even a myth contains concealed within its kernel the origin of this valuable addition to man's comfort, as that of Prometheus reveals the source of fire. The legends told by Pliny and Josephus of pirates or Jews using blocks of soda to support their fire, and thus accidentally discovering glass, refute themselves before the light of scientific inquiry. No ordinary wood fire would thus convert sand and soda into glass. More probably miners smelting metals, noticing some vitreous remains amongst the slag, admired and imitated them; or it might be that potters saw a glaze run over some of the pottery that they were baking. But however the art originated, we know that in the early times of the Egyptian empire, before even the period usually assigned to the exodus of the Israelites, glass was made into bottles and beads, and one of the latter exists, having on it the name of a king of the eighteenth dynasty, who lived about B.C. 1500. Later on these same Egyptians manufactured vases, cups, perhaps lamps, and certainly mosaics, and understood the art of glass-cutting. Glass-blowers are portrayed at work both at Thebes and at Beni-Hassan, and Alexander the Great is said to have been buried in a coffin of glass. Glass was used for bottles for wine, some of which were enclosed in wicker-work and some in leather; but more remarkable still is the discovery in Egyptian tombs of several bottles inscribed with Chinese letters—pointing, it would seem, to an Oriental origin for this art.

From Egypt the manufacture of glass slowly spread to the other coasts of the Mediterranean, to Phœnicia, to Greece, and to Rome. The Phœnicians at an early period made some marvellous works, if we believe, as seems most credible, that the huge emerald pillars mentioned by Herodotus, as seen by him in the Temple of Hercules at Tyre, were some of those artificial gems for which the Egyptians and Phœnicians were for a long time celebrated. To Greece the art took a long time to penetrate, and but little seems to have been done by the Greeks until they had lost their independence and had come under Roman rule, when the Romans themselves were already excelling in the same line. Under the Emperor Tiberius great encouragement was given to workers in the art of glass-making, and subsequent emperors were great connoisseurs of the elegant creations in this material.

The first use of glass for windows seems to have originated soon after the period of which we have just been speaking—viz., in the first centuries of the Christian era. Seneca, who lived in the third century, is the first author who distinctly mentions such an application of the material; but a pane was found at Herculaneum, a city which we know was overwhelmed A.D. 79. Here, again, we are at a loss to know where the next step was made, of introducing coloured glass into windows, or, indeed, whether this was another step, and not one and the same. Many people, considering that it is far easier to make glass of some of the commoner colours than to produce that which is perfectly colourless and transparent, have supposed that coloured windows preceded those of clear glass. This is probably true, but the early windows were made either of glass of one colour only or of slight modifications of one colour. It was as much another stage to introduce a pattern, with distinct and contrasted colours, as it was to introduce transparent and colourless glass. Chrysostom speaks of windows of divers colours. The church of St. Sophia at Constantinople is said to have had coloured glass windows in the sixth century; but the earliest coloured windows of which we know the precise date were those made for Pope Leo III. in 795, to be inserted in the Church of St. John Lateran at Rome; and the earliest date that can be relied on at Constantinople is A.D. 949, when Constantine VII. sent his portrait, beautifully painted on glass, to Abderrahman, the Moorish monarch at Cordova, in Spain. This, of course, must have been produced by colours laid on the surface of the glass, and not burnt in; in fact, the latter improvement is attributed to either the Germans or Flemings at a much later date. The yellow stain produced by silver is said to have been the result of an accident which happened about the beginning of the sixteenth century—some say to Van Eyck, others to Fra Giacomo da Ulmo. The latter is said by Vasari to have dropped a silver button into the lime of the furnace in which he was about to burn some painted glass, and that the silver, touching the heated plates, caused a yellow discolouration, which accidental circumstance he, like a true observer, immediately turned to account.

Into Gaul the art of making and colouring glass had been introduced in the earliest centuries of the Christian era, and about the eleventh century it had begun to flourish, being advanced and nourished, like many other of the fine arts, more especially by its dedication to ecclesiastical purposes, for decorative glass does not seem to have been used in private houses until nearly the sixteenth century. Between 1399 and 1429 the hotel of the Duke of Orleans in the Rue de la Poterne les Saints Pol in Paris was adorned with coloured glass, which, however, on being at a somewhat later date cleaned and washed, required renovating and colouring afresh, so that evidently the colours were not burnt in.

Bede says that glass and glass-makers were brought to England as early as A.D. 674, but the art does not seem to have flourished greatly here, for Matthew of Paris says that in the time of Henry III. only few churches had glass windows; but after this it must have rapidly arrived at perfection, for the colours, and especially the blue, of twelfth century glass are such as have been surpassed at no subsequent period.

The process since that time has not materially altered. Slight improvements have been made, and at one time a portion of the art had been lost. This now has been recovered; but though we can trace stages of development running parallel to the different stages of architecture, there have been no great revolutions in the art down to the present day.

Having now drawn a slight sketch of the progress from the earliest known specimens of glass down to the period at which this decorative art was practised in its greatest perfection in our own country, it is time to give some notice of how the process of painting upon glass is carried on; and here we would draw attention to the difference between stained and painted glass. Stained glass is that which is coloured in its manufacture; the painting is a shade burnt into the glass at a subsequent period, so that most windows contain stained glass painted. In the early days of painting glass, colours were simply applied with white of egg or oil, or some such convenient vehicle to the uncoloured or so-called white glass; the picture was afterwards varnished, and the whole was complete. At a later period, when the art of burning in the colours was discovered, the former process was considered insufficient, and for all works of any importance it has been discarded, and will not be further referred to by us. The present process is really the production of a species of enamel on the surface of various coloured glasses, thereby producing various degrees of transparency.

We shall now speak of the various stages that have to be passed through before a window can be put into the opening for which it is designed, and we shall do this as if the work were entirely carried through by the same individual, though any one will see at once that the labours at the furnace and the artistic manipulations are not likely to be performed by the same pair of hands in these days of minute subdivision of labour.

The first requisite is a careful design, and the circumstances of the case necessarily remove the art of designing windows both from painting and from mere mechanical designing, such as that used for ordinary art manufactures. The next step is the production of the glass itself—its colouring—and here we must note the difference of its manufacture, both from that of transparent glass used in ordinary windows, and that of coloured glass employed for ornamental purposes. We must next look to certain peculiarities of English and foreign manufacturers, and notice how brightness of light and delicacy of colouring is produced. After this the glass has to be cut to the required shapes, to be set up, and at length painted. These stages we shall describe. Then the various styles of shading, and their effects, will engage us for a short time before we follow our picture to the furnace, in which its shades and stains are indelibly fixed. After this the putting the whole together, and fixing it in its required place, will complete the work.

Our future papers on the art of painting on glass, which is one of the most interesting processes connected with the practical application of the fine arts to industrial work, will be accompanied by illustrations, which will not only be of great use and value to the student of this beautiful decorative art, but also furnish suitable studies for enlargement, to be coloured subsequently, to show the general effect of the composition when executed in painted glass.

THE ELECTRIC TELEGRAPH.—IX.

By J. M. Wigner, B.A.

THE RELAY—AUTOMATIC TELEGRAPHS—BAIN'S—WHEATSTONE'S—THE SOUNDER.

In the embossing Morse instrument described in our last, it is clear that the electro-magnet must possess sufficient power to press the style rather firmly against the riband. In the ink recorder a certain amount of pressure is likewise required. Now, we find that when the electric current has to travel over a very long circuit its power is considerably reduced, and even if we increase the battery power there is an increased resistance, so that we cannot transmit to very great distances a current sufficiently powerful to print its own messages. In shorter circuits defective insulation, and other similar causes, often prevent the message being duly recorded.

At first sight this appears a serious difficulty; but it has been met and entirely removed by a most simple but ingenious piece of apparatus called a "relay." By means of this the current arriving by the line-wire calls into action the battery at the receiving station, and this local battery is then made to print the message in its own instrument.

Many different forms are given to the relay, and one of the simplest of these is shown in Fig. 38. A bobbin (or sometimes two placed side by side) is secured to the stand of the instrument, the ends of the wire which round it being connected with binding-screws, situated one at each side of the instrument. The line-wire is connected to one of these and the earth-plate to the other, so that the current as it arrives merely traverses the coils, and passes on to the earth. The keeper of the electro-magnet is mounted on a lever which turns on a pivot at A, so as to vibrate with as little friction as possible. The upper end of this lever plays between two set-screws, B and C, by which its motion is regulated as required. A delicate spiral spring is affixed to its upper end, and keeps it, when no current is passing, resting against the tip of B, which is covered with a piece of agate or other good insulating material. The other end of the spring is connected to a cord which passes through a loop, and is then attached to a small reel moved by the milled head D. In this way it can be adjusted so as just to keep the lever pressing against B, but at the same time to allow it to yield to the faintest attraction from the magnet.

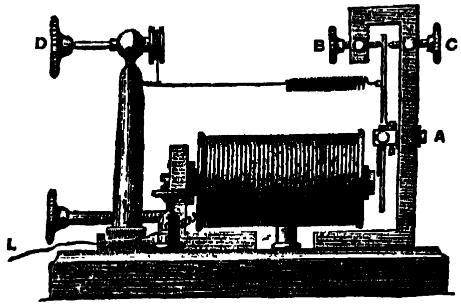

Fig. 38.

The recording instrument is now placed in circuit between C and one pole of the local battery, while the other pole is in communication with the axis A on which the lever turns. The manner in which the instrument acts will now be manifest. The circuit of the receiving instrument is interrupted between the point of C and the lever; the agate tip of B preventing any circuit through that.

Now if a current passes along the line-wire and round the bobbin, it at once converts it into an electro-magnet, and overcoming the tension of the spiral springs brings the lever into contact with C, and thus sets the recorder to work. To ensure contact, the tip of C, and the surface of the lever under it, are both covered with platinum. In this way the style moves just as it would if the current from the line-wire passed through the instrument itself, but there is sufficient power to print the message distinctly.

It will easily be seen that by means of relays suitably arranged any message arriving at a station can be actually made to re-transmit itself to any other station or stations without any assistance from the clerk in charge. The telegraph thus becomes almost automatic, and we have in this an illustration of the marvels that may be accomplished by the aid of science.

A difficulty has been found to exist in very long lines, and especially in submarine cables, in the transmission of messages even with the relay, and it has been suggested to make one or two breaks in the line, and at each to introduce a relay and a new battery. The project of laying the Atlantic cable in three sections, with relay stations at Greenland and one other place, was some few years ago seriously discussed.

The greatest speed attainable with the Morse, under ordinary circumstances, is about thirty-five to forty words per minute. The hindrance, however, to a greater speed, is not in the instrument or the power of the electric current, but in the labour required for the transmission; and when we consider that on an average ten or twelve distinct signals have to be given for every word sent, we are only surprised that this extreme rate can ever be attained. The lines and instruments are, however, capable of accomplishing more than this; and hence means have been sought of increasing the speed of transmission, and thus accomplishing a greater amount of work without increasing the number of line-wires or instruments, since these add so greatly to the cost.

One plan that has been tried, especially on the Continent, consists in setting up the message in type; this is not made on the ordinary plan, but cut out of sheet brass in such a way that the elevations in it correspond to the marks in the Morse alphabet. This type is placed on a metal tray connected with the line-wire, and is made to travel rapidly under a small spring connected with one pole of the battery. Thus at every elevation in the type a current is transmitted, the duration of which is regulated by the arrangement of the type. Fig. 39 will illustrate this, the word "Morse" being here shown as set up in the type.

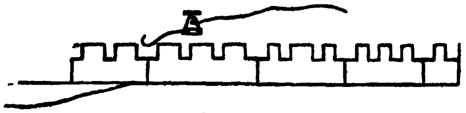

Fig. 39.

In this way several clerks may be occupied in setting up the messages, which may be successively transmitted at a very great speed, all of them being transmitted along one wire. The strip of paper at the receiving station must, of course, be made to move in this case at a greater speed than usual. Besides the saving thus effected, there is an additional advantage attained by setting up a message in type, and this is that the same message may easily be sent in succession along different lines. In the case, for instance, of the Queen's speech in opening Parliament, the same message has to be sent to almost every town in the kingdom, and if once set up the same type may be run through each instrument.

In this country, however, a somewhat different plan is adopted. There are, in fact, two systems of *automatic* transmission, invented respectively by Bain and Wheatstone, which have been tried. In both of these the message is punched in a strip of rather stout paper, which is then drawn through the transmitting apparatus. Bain's instrument was the earlier of the two, and was originally worked for some time on the line from Liverpool to Manchester, a speed of about seventy words per minute being attained. Difficulty was, however, experienced in procuring a perfect arrangement for punching the paper, and the insulation of the lines was likewise defective; this impeded the speed of the messages, and the use of the instruments was discontinued.

The strip of paper was punched with the same signs as those received in the ordinary way, the embossed part being removed by the punch. A strip of paper with the word "Bain" punched on it is shown at Fig. 40. When thus punctured, it is drawn over a metallic roller connected with the line-wire, while a narrow metallic spring presses on its upper surface, and thus comes in contact with the roller wherever one of the spaces occurs. The end of this spring is usually divided into two or three prongs, so as to ensure a contact being made, and thus it will be seen currents of varying length are transmitted, just as when the ordinary Morse key is used. In the case of a long message several operators may commence punching it at different parts, and the separate strips may easily be joined together and drawn through the instrument.

Fig. 40.

In Wheatstone's Automatic Telegraph the message is likewise punctured on a strip of paper, but in a somewhat different way. Three punches are placed side by side, the middle one being rather smaller than the others. A stud for striking with the band is connected to the head of each, and the riband is drawn under them.

The small centre punch is merely used to space out the words and letters, the one which is at the upper side being used to represent the dots of the Morse Code, and the lower one for the dashes. The strip, when punched and ready for transmission, presents the appearance shown in Fig. 41. The word "Wheatstone" is here punched in it.

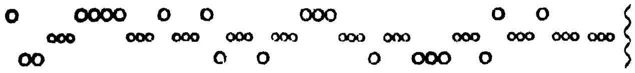

Fig. 41.

The punching apparatus used is so arranged that the paper is moved forward a small interval at each descent of a punch, and thus the proper spacing of the words and letters is attained.

The transmitting apparatus required with this strip is, like the receiver, of a special construction. Three parallel wires are made to descend at constant intervals upon the strip as it is moved onward, and the connections are so arranged that when the upper wire passes through an opening and touches the metal underneath, a positive current is transmitted, while the lower wire in like manner produces a negative current.

In the receiving instrument there is a small reservoir of ink with two minute apertures in its under surface, so small that the ink cannot flow through them. The strip is drawn under this, and two polarised electro-magnets are so arranged, that when a positive current is received one of these forces a small pointer through the right-hand aperture, and thus produces a dot on this edge of the strip; when a negative current is received, the other magnet is called into play, and produces a similar dot at the other side of the strip. The message as received then will present the appearance shown in Fig. 42. The merits of this system are increased speed and greater accuracy. The punches are very easily and rapidly worked, but long-continued striking tends to render the hands somewhat tender, and hence in some cases the punches are worked by steam, and a gentle touch suffices to allow the punch to act on the paper placed under it. A single wire will with this instrument keep several punches at one end and several readers at the other fully occupied.

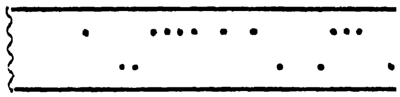

Fig. 42.

The Queen's speech on opening Parliament in 1871 was transmitted to many of the principal towns in England by this instrument, and in one case a speed of 94 words per minute was attained. This was between London and Bradford, and the wire was, of course, in very good condition as regards conductivity and insulation. The speech contained 1,780 words, and the length of the riband on which it was punctured was a little over 111 yards.

On the same occasion the speech was transmitted to various places by the ordinary Morse instrument, and the greatest speed attained was on the line to Brighton, the whole message being transmitted to that place in 43½ minutes, that is, at an average speed of about 40 words per minute. This is the greatest speed ever recorded as being continued for such a length of time: a few abbreviations were, however, used.

As we have already mentioned, a peculiar clicking sound is produced by the Morse instrument when at work. This is caused by the oscillating lever striking against the set-screws which regulate its play, and thus two taps are produced for every sign transmitted. When the dot is sent these taps succeed one another very rapidly, but with the dash a longer interval elapses. An unpractised ear will, of course, be quite unable to discern this, but an experienced clerk is frequently able to receive and write down the message from the sound alone, without even looking at the strip. The instrument may indeed be said to dictate it to him, and he writes it by ear.

The great advantage of this is at once apparent, but in this country it is not considered well to receive the message in this way alone. The strip is therefore always allowed to receive the message, and this can be referred to, if necessary, so as to ensure greater accuracy. In America, however, many clerks read entirely by ear, and instruments known as "sounders" are especially constructed for the purpose.

The "sounder" consists of an electro-magnet suitably mounted. Its keeper is fixed to a lever, at the other end of which is a small hammer made to play between two anvils. These are so arranged that a less intense sound is produced by the upper than by the under one, and by means of adjusting screws and a spiral spring the exact sound of each can be regulated.

This instrument is much simpler in its construction, and has in most parts of America quite superseded the other form. There is, however, one serious drawback to its employment, and that is the fact that no written record is left. It is stated however, that much fewer mistakes arise when it is employed, and that the ear is found to be much more reliable than the eye.

VEGETABLE COMMERCIAL PRODUCTS.

XXI.

MISCELLANEOUS PLANTS OF COMMERCIAL VALUE (*concluded*).

Cork Oak (*Quercus suber*).—This tree closely resembles the *Quercus ilex*, L., or evergreen oak, so well known in English shrubberies. It is indigenous to the mountainous regions of Spain, Portugal, and the south of France. It grows from thirty to forty feet high, and from two to three feet in diameter. Spain and Portugal supply the greatest portion of the cork which is used in Europe; abundant supplies are also received from the south of France at the foot of the Pyrenees, the islands of Sardinia and Corsica, and the forests of Algeria.

GATHERING THE BARK OF THE CORK-TREE.

When this tree is about five years of age, the cork, which composes the greater part of its bark, begins to increase in a very remarkable manner. Nearly all its vegetative activity seems to be concentrated on this part, which grows unusually large, thick, and spongy. If left on the tree it becomes cracked and so deeply fissured that it is unfit for use. It is therefore removed before this happens. Its removal does not injure, but is beneficial to the tree, for if the cork is allowed to remain on its stem, the cork-oak seldom lives longer than fifty or sixty years; if, on the contrary, it is removed, the tree flourishes sometimes for upwards of 150 years. After the tree is thirty years old its cork may be removed at intervals of from six to ten years. The first crop of cork is generally inferior in quality, and is principally used for making floats for fishing nets. The crops are usually gathered in the months of July and August. Two opposite longitudinal incisions into the bark are made the whole length of the stem, and then several transverse ones about three feet apart. The bark is now beaten to separate it from the subjacent liber, and detached in cylindrical pieces by inserting under it the handle of the instrument, which is curved and made thin at its extremity for this purpose. In effecting this removal great care is taken not to injure the newly-formed suber or cork—viz., the living layer of cork beneath. After barking, the pieces of cork are slightly charred to close the pores, then loaded with weights to flatten them, and finally stacked in square masses in some dry place, where they remain for two or three months. In drying they lose about one-fifth of their weight.

Only when the trees are forty or fifty years old is the bark sufficiently matured for making good corks. This substance is valuable for bottle corks, because it is light, porous, compressible, and sufficiently elastic to adapt itself to the neck of a bottle. It can be cut into any shape, and, notwithstanding its porosity, is impervious to any common liquid. These qualities make it superior to all other substances as a stoppering for bottles, for which it is principally used. Corks are made as follows:—

The cork is first cut into slips, which by means of a gauge are made narrow or wide, according to the size of the corks or bungs ordered; these slips are then cut into squares of the required length, which are cut circularly with a knife by the hand, and thrown into a basket. Cork-cutting in Catalonia and the south of France is a branch of manual labour which furnishes a livelihood for a considerable portion of the population. Several attempts have been made to cut corks by machinery, but they have hitherto failed to supersede hand labour.

Cork is largely manufactured into soles for boots and shoes. Cork legs, hat frames, mattresses, bolsters, life-preservers, and lifeboats are also manufactured from cork. Coffins were made of it by the ancient Egyptians. Many of the wealthier inhabitants of Spain have their houses lined with cork, which ensures the freedom of the rooms from damp. Cork, in thin slips, is used by entomologists as a lining to drawers and cabinets in which to fasten their insect pins. Spanish black and a black colour for painters are made from the calcined parings of cork.

The quantity of cork annually imported into the United Kingdom is about 3,000 tons. The price per ton varies from

£17 to £50, according to quality. The Spanish cork is the best, and fetches the highest price. Unmanufactured cork is admitted into England duty free. The duty on corks ready made is eight shillings per pound; corks only squared and rounded pay sixteen shillings per cwt.; and fishermen's corks two shillings per cwt.

Balsa (*Ochroma Lagopus;* natural order, *Sterculiaceæ*).—The wood of this tree, being soft and light like cork, is used for stopping bottles. The never-sinking rafts, which at the discovery of South America caused such surprise, were constructed of it, and are so still. This tree prevails along the coasts of South America and the West Indies. The silky hair of the capsule of this plant, as well as that of other species of the order, is employed for stuffing pillows and cushions.

Soda and **Potash**, which occur abundantly in plants, are important articles in commerce, and the plants which yield them are therefore deserving of notice. A large proportion of the plants growing on sea-coasts contain soda, whilst inland plants contain potash. Various species of *Salsola*, especially *S. kali*, *S. Salicornia*, and *S. Kochia*, furnish the soda of commerce. The best soda comes to us under the name of barilla, which is, in fact, the incinerated ash of *Salsola kali*. This plant is carefully cultivated in the Spanish provinces of Murcia, Valentia, Carthagena, Malaga, and Alicant, which carry on a considerable trade in the article.

"The seed is sown in light soils, which are embanked towards the sea-shore, and furnished with sluices for admitting an occasional overflow of salt water. When the plants are ripe, the crop is cut down and dried, the seeds are rubbed out and preserved, and the rest of the plant is burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semi-fusion, so as to concrete on cooling into cellular compact masses. The most valuable variety of this article is called *sweet barilla*. It has a greyish-blue colour, and becomes covered with a saline efflorescence when exposed for some time to the air. It is hard and difficult to break; when applied to the tongue it excites a pungent alkaline taste."* An inferior soda is made in France, England, Ireland, and the Shetlands, from sea-weed, and brought into commerce under the name of kelp. Large revenues are derived by the proprietors of the shores of the Scottish islands from the incineration of sea-weed by their tenants, who usually pay their rent in kelp. Carbonate of soda is now made from common salt (chloride of sodium), yet the burning of sea-weeds, etc., is still largely followed for the sake of the iodine contained in the ashes.

Potash is prepared for commerce by evaporating in iron pots the lixivium of wood-ashes; hence the name *potash*. The potash in plants is very soluble in water. If the wood-ash, which is an impure carbonate of potash, be put into water, and quick-lime be added to the solution, the lime will abstract the carbonic acid from the carbonate of potash, and form an insoluble carbonate of lime, which will be precipitated, and the potash will be taken up by the water, which will thus be rendered powerfully alkalinic. The lixivium or clear alkaline liquor thus obtained is then decanted off, and evaporated to dryness in iron pots, the residuum is calcined to remove all organic matter, and the product thus obtained forms the crude potash of commerce. The different varieties of potash are named either after the locality in which they are produced, or the route by which they arrive. Thus we have American, Russian, German, Illyrian, Saxon, Bohemian, and Heidelberg potashes. When still further purified, by additional calcination, potash is termed pearl-ash.

Potash can only be obtained abundantly in countries where there are vast natural forests, and where wood is so cheap that it only costs the labour of felling and hauling. In many parts of America, where timber is an encumbrance on the soil, it is felled, piled up in pyramids, and burned, solely with a view to the manufacture of this product.

Potash is a very considerable article of commerce. Russia produces annually over 300,000 cwt., which are exported from Petersburg, Riga, and Archangel; and from Poland, *viâ* Warsaw and Cracow; from East and West Prussia, *viâ* Dantzic and Konigsberg, vast quantities of potash are also exported. Hungary produces annually 150,000 cwt. of potash, of which 50,000 cwt. go to supply the demand in Bavaria and Saxony. The Harz district, the forests of Thuringia, and almost all parts of Germany rich in wood, supply potash. In modern times, however, it is received in the greatest quantities from Canada and the United States, *viâ* Boston and New York.

Potash is largely consumed in the manufacture of glass, porcelain, earthenware, and gunpowder; in colour and chemical manufactories; and also in dyeing and bleaching.

Tinder.—The internal spongy portion of several species of *Polyporus*, soaked in a solution of nitre, forms tinder. The principal places for the production of this fuel are, besides Hungary, Poland, Sweden, and Alsace, the country around Ulm, Nuremberg, Augsburg, and Frankfurt in Germany. Germany supplies the French, English, and Dutch markets, and Sweden the countries around the Baltic.

Fuller's Teazel (*Dipsacus Fullonum;* natural order, *Dipsacaceæ*).—This plant is closely allied to the *Compositæ*, but differs in having free stamens, and a pendulous ovule. It is valuable for its large conical composite flower-heads, which have hard stiff bracts, the sharp points of which are hooked. These bracts remain after the flowers have died, and their points are so admirably adapted for raising the nap on woollen cloth, that no invention has yet been found to supersede them. Many carding machines have been introduced, but the best clothiers still prefer the teasel for finishing their cloth. For this purpose the conical teazel heads are cut up into halves and quarters, and fixed into a cylindrical frame, with the hooked bracts outwards, which frame is made to rotate over the surface of the cloth, until the little sharp hooks of the teazel have scratched up the required nap. Teazel heads, under the name of weavers' carders, are an extensive article of commerce, and cultivated in France, Italy, Holland, Germany, and the West of England. Large quantities are annually imported into the United Kingdom from Hamburg and Holland. The teazels are made up into bundles for sale to the clothiers, each bundle containing from 9,000 to 10,000 plants. In addition to our home produce, 14,022,384 teazel heads were imported in 1853.

Bulrushes (*Scirpus lacustris*, L.; natural order, *Cyperaceæ*).—The bulrush, or bull-rush, grows along the margins of rivers, lakes, and ponds, especially in Northern Europe and the Netherlands. This plant is used in making the seats of rush-bottomed chairs; it is also in great demand among coopers, who place it between the staves of casks intended to hold liquid. The pithy structure of the rush induces the swelling of the culm, and the interstices between the staves are thus closed, and the cask rendered water-tight. Many vessels laden with this rush arrive annually in England from Holland and Belgium, bringing thirty or forty tons of rushes each voyage. This is a very large quantity, considering the lightness of the material. More than 1,000 tons of bulrushes are annually imported into the United Kingdom.

Soft Rush (*Juncus effusus*, L.; natural order, *Juncaceæ*).—The pith of the common soft rush, as also that of *Juncus conglomeratus*, is employed for making the wicks of rush-lights, which continue to be used, although not so much as formerly.

In Japan, the manufacture of mats, etc., from rushes, is a regular trade. The floors of their houses are covered with rush mats of great beauty and variety, and rush mats are the only carpets and beds used by the Chinese. A light sort of matting made of the same material is used as a window blind. The sugar sent home from the East Indies is packed in bags made of rush-matting. The size of the Japanese rush mats appears to be regulated by law, for they are all of the same magnitude throughout the kingdom, the only exception being the mats in the imperial palace at Jeddo. Rushes are also used for chair bottoms and baskets.

Dutch Rush (*Equisetum hyemale*, L.; natural order, *Equisetaceæ*).—Used for polishing hard woods, alabaster, marbles, and other substances, for which purpose it is well adapted, by the large quantity of silex which is contained in its cuticle. The invention of sand and emery papers in modern times has, however, now almost superseded this natural polisher. It is still much used in Holland, where it grows abundantly in low boggy ground; it is found in damp woods in this country, but is occasionally imported from Holland.

Bast (*Tilia Europæa;* natural order, *Tiliaceæ*).—The common linden or lime-tree is easily recognised by its obliquely cordate, unsymmetrical leaf, and the curious bract to which the peduncle or flower-stem adheres. In Northern Europe and

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* "Ure's Dictionary of Arts, Manufactures, and Mines," vol. iii., p. 705. 1867.

Russia, bast mats, ropes, and twines are made from the inner fibrous bark of this tree. At the proper season the stems are cut longitudinally, and the bark is taken off in long strips. The outer bark is easily separated from the inner; and the latter dried constitutes the bast of commerce. This is plaited by the Russians into mats from a yard and a half to two yards square, which are much used by gardeners and upholsterers. These mats are also employed for lining the holds of vessels intended to receive corn. Not fewer than 14,000,000 are annually imported into the United Kingdom from various Russian ports, but chiefly from Archangel.

AGRICULTURAL CHEMISTRY.—VIII.

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CHAPTER VIII.—NITROGENOUS MANURES.

THE most valuable kinds of manures at present employed are those which, owing to the large amount of nitrogen which they contain, are termed nitrogenous. In this chapter we propose to describe the more important fertilisers which act chiefly by means of their nitrogen, but some of which are also more or less useful on account of the phosphates and alkaline salts which they contain.

Peruvian guano is the most generally employed nitrogenous manure. The term "guano" is a corruption of the Peruvian (Indian) word *huano*, signifying dung. During countless ages this manure has been employed in Peru, and in such high estimation was it held, that any person detected in the act of killing the sea-fowls whose dried excreta constituted this manure, was liable to be punished by death. We need not feel surprised at the protection afforded to the guano-producing birds, when we learn that large tracts of country would have remained unproductive were it not for the liberal application of guano to their soils.

In Peru rain is a rare phenomenon, and the temperature is very high. The conditions for the preservation of the excreta of birds are therefore most favourable in this climate. Countless sea-fowls frequent the isles and rocky promontories of the coasts, and their excrements are rapidly dried, and in a manner baked immediately after being voided. The dried excreta is to a large extent soluble in water; but in Peru there is no rain to wash away the soluble ingredients of the guano, and consequently little save water is lost by evaporation or solution. In other countries, where bird-manure accumulates in certain places, the rain washes away the greater portion of the alkaline salts, whilst by fermentation, induced by the united influence of moisture and heat, a portion of its nitrogen escapes in the form of ammonia, and the rest is perhaps altogether washed away by rain.

Peruvian guano contains large proportions of ammonic urate, oxalate, and phosphate, various alkaline salts (compounds of the metals sodium and potassium with acids and chlorine), calcic phosphate, and organic matter. Until recently an average sample of Peruvian guano had the following composition per 100 parts:—

Moisture	12
Nitrogenous organic matter and ammoniacal salts.	56
Yielding ammonia	(16)
Tricalcic phosphate (tribasic phosphate of lime)	22·5
Alkaline salts	9
Insoluble mineral salts	0·5
	100·0

As the annual importations of Peruvian guano into these countries amount to hundreds of thousands of tons, and as three-fourths of its value (when of good quality) are due to its nitrogen, the proportion of that ingredient in a sample of guano is a matter of prime importance to the purchaser of the article. The importations during the present year have, however, been of a most variable character, although formerly no manure possessed a more constant composition than Chinchas Islands (Peruvian) guano. In very few samples has the per-centage of ammonia[*] risen to 16, whilst in many but 9 per cent. of this constituent has been found. The importers of Peruvian guano refuse to guarantee the presence of any particular amount of ammonia; hence the purchasers of this once standard manure are liable to pay £12 or £13 for an article that may not be actually worth £9.

Peruvian guano is frequently largely adulterated with clay, plaster of Paris, ochre, and inferior phosphatic guanos. We have often examined Peruvian guano containing from 30 to 60 per cent. of fraudulently added earthy or other useless matters. When genuine and of good quality, this kind of guano has a light brown or greyish colour. It consists of powder commingled with hard lumps, which on being broken exhibit a lighter colour and a crystalline appearance. A bushel of good guano weighs about seventy pounds, whilst adulterated kinds often weigh more than a hundred pounds per bushel. A rough test of the purity of the article is to burn three-quarters of an ounce of the suspected sample upon a piece of tin or iron placed on a clear fire. If the residue be not more than a quarter of an ounce, the guano is probably pure; but if the residue amounts to half an ounce, the sample is either extremely inferior, or grossly adulterated. Guano adulterated with ochre or clay has usually a dark-brown colour, and it is much colder to the touch, and feels heavier than good Peruvian guano.

Peruvian guano is largely used as a manure for cereals; it is also commonly applied to green crops, but superphosphate of lime is more generally used for the latter. A mixture of two parts of superphosphate of lime and one of Peruvian guano usually gives good results when applied to mangolds, turnips, and other root-crops. The best results follow the use of this manure when it is applied to heavy clays containing but little organic matter; light soils, on the contrary, appear to be more benefited by the application of phosphatic manures.

Sal-ammoniac, or ammonic chloride, and ammonic sulphate, are very valuable nitrogenous manures; indeed, it is probable that it is their ammonia alone which is useful to plants. When coal is submitted to what is termed destructive distillation, for the purpose of preparing illuminating gas, the small proportion of nitrogen which the fuel contains unites with part of the hydrogen, and forms the gas termed ammonia. The gases evolved from the highly-heated coal are passed through water, which dissolves nearly all the ammonia, and some tarry matters, carbonic acid, and sulphuretted hydrogen. The water saturated with these matters is termed gas liquor, or ammoniacal liquor, and it is the source of nearly the whole of the ammonia and ammoniacal salts manufactured in the United Kingdom. This liquor is put into large tanks, and heated by steam-pipes. The ammonia is driven off, and forced into vessels containing either sulphuric acid or muriatic acid (chlorhydric acid). The acid and ammonia unite, producing a sulphate or muriate, as the case may be. The solution of the ammoniacal salt is next boiled down, and the salt crystallised.

Commercial ammonic sulphate contains about 25 per cent. of ammonia, and sal-ammoniac 30 per cent. of ammonia. In the former salt there is sometimes present a salt termed sulphocyanide of ammonium, which is poisonous to plants. The presence of this compound may be detected by adding to a solution of the ammonic sulphate a few drops of solution of ferric chloride or sulphate (perchloride, or persulphate of iron) which has the effect of producing with the sulphocyanide of ammonium a deep red colour.

The ammoniacal salts supply nitrogen to plants, and these are most efficacious when applied to the cereals and the natural grasses. The leguminous crops are not always benefited by the application of ammonia salts.

Gas liquor, diluted with four times its bulk of water, may be employed as a liquid manure. It is an excellent addition to the compost heap. Gas lime (the refuse lime, containing certain impurities derived from coal gas) is held in high estimation as a manure, but we believe it to be seldom worth the cost of its carriage from the gas works to the field. It contains only a trace of ammonia, and it is merely the lime of which it is mainly composed that renders it at all useful.

Soot is used largely for manurial purposes. It consists of carbon (charcoal), salts of ammonia, gypsum, and other minerals, and various organic bodies. The amount of ammonia varies from 1 to 6 per cent. This manure is used chiefly as a spring top-dressing to pastures and meadows. Dried blood, hair, leather clippings, feathers, horn shaving, shoddy, and woollen rags are used for manurial purposes. They contain about a sixth part of their weight of nitrogen; but with the exception of dried blood, they decompose extremely slowly in the soil. Shoddy and woollen rags may be rendered immediately available by steeping them in strong sulphuric acid for a few days. Their decomposition may also be hastened by incorporating them with a compost in a state of active fermentation. The artificial manure manufacturers often use these articles as cheap sources of nitrogen, but for this purpose they are not nearly so valuable as ammonic sulphate, guano, or blood.

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[*] 14 parts of nitrogen are equivalent to 17 parts of ammonia. In guano only a portion of the nitrogen exists in the form of ammonia; the rest is a constituent of uric acid and other nitrogenous bodies.

Rape-cake, at one time used exclusively as a manure, is now largely employed as a food for stock. It decomposes readily enough in the soil, and its action is seldom felt after the first year. In every 100 pounds there are about 6 pounds of nitrogen, 2¼ pounds of phosphoric acid, and 2 pounds of alkaline salts. It is chiefly used as a manure for wheat, and may be either drilled in with the seeds or applied as a top-dressing in the spring.

Sodic nitrate (nitrate of soda or cubic nitre) is one of the best top-dressings applied to the cereals; under its influence the sickly yellowish colour which growing wheat sometimes assumes is generally changed into a healthy green. Commercial sodic nitrate contains about 17 per cent. of nitrogen, somewhat less than is yielded by ammonic sulphate.

Before being applied, sodic nitrate should be mixed with three or four times its weight of ashes, common salt, or some such material, and it should be applied as equably as possible to the soil. These observations apply equally to all the concentrated manures. When sodic nitrate is pure it evolves, when thrown into the fire, a fine yellow light; but if adulterated with common salt, the colour is greenish-yellow. Dry sodic nitrate contains 63·53 per cent. of nitric acid, which is expelled from the salt at a red heat. If an ounce of the nitrate does not lose by prolonged ignition nearly two-thirds of an ounce, it indicates some such adulterant as sodic sulphate (Glauber salts) or common salt.

PRACTICAL PERSPECTIVE.—IX.

THE object of this lesson is to show the method of putting into perspective an object when placed at an angle to the picture, *and at a distance from the foreground.*

Let us, in the first place, recapitulate the method of projecting the object when one of its angles touches the picture-plane.

In Fig. 44 B C E D is the plan of the cubical figure which is to form the subject of the lesson.

Having drawn the picture-line, horizontal line, and line of direction, and having fixed the station-point S, construct at S the angles G S H and I S J equal to the angles C B E, D B F in the plan, and produce the lines S G and S I to meet the horizontal line in VP1 and VP2 (the last-named point is not shown in the figure); from VP1 and VP2, with radius extending to S, describe arcs cutting the horizontal line in MP1 and MP2.

Now at B′ (the distance of the nearest angle of the object on the right of the spectator) erect a perpendicular B′ F, equal to the height of the object, and from B′ draw lines to the vanishing-points; set off on the picture-line the lengths B′C and B′ D′ equal to B C and B D on the plan, and draw lines to the measuring-points. These lines will, as already shown, cut those drawn to the vanishing-points, and thus give the positions of the edges, which will stand perpendicularly on the points C and D in the plan.

From F draw lines to the vanishing-points, and then the perpendiculars *c* and *d* will complete the projection of the object.

We now proceed to delineate the object when placed on the left of the spectator and within the picture (Fig. 45).

It will, in the first place, be necessary to find the points of distance, and it will be remembered that these are at the same distance from the centre of the picture as S. Therefore from C, with radius C S, describe a semicircle, cutting the horizontal line in the points PD1 and PD2.

Now find the vanishing-points and measuring-points. In the present case these are the same as have been used in Fig. 44.

In the first instance, mark the point *b*, which would be the situation of the front edge of the object if it were in the immediate foreground.

Now, as the object is to be moved directly backward, it will travel in a line at right angles to the picture-plane, and such a line will vanish in the centre of the picture. Therefore—

From *b* draw a line to C, and

From *b* set off *b x*, representing the distance which the object is supposed to be within the picture; and from *x* draw a line to the point of distance, cutting *b* C in *b′*.

Through *b′* draw a horizontal line, called the *movable base-line*, and this, in the actual working of the subject, will take the place of the picture-line.

Now on each side of the point *b* on the picture-line set off the real length of the sides, as per plan—viz., *b c* and *b d*—and from these points draw lines to the centre of the picture, cutting the movable base-line in *c′* and *d′*. The movable base-line is thus divided proportionately to the corresponding portion of the picture-line,* and now the work can proceed in a manner precisely similar to that in Fig. 44

From *b′* draw lines to the vanishing-points, and from *c′* and *d′* draw lines to the measuring-points, cutting these in *c″* and *d″*.

At *b′* erect a perpendicular for the front of the object; but the question now arises, how to cut this off at the required height, for, of course, as it is in the distance, the real height will be diminished, but how much? Now it will be remembered that the whole object has moved backward in a direct track from the point *b* in the foreground. Therefore draw at *b* a perpendicular of the true height of the object—viz., *b f*—and from *f* draw a line to the centre of the picture, cutting the perpendicular *b′* in *f′*.

Then *b′ f′* is the perspective height of the front perpendicular of the object, for it will be seen that it is a portion of a plane standing in the line from *b* to C, and bounded at the top by the line *f* C.

From *f′* draw lines to the vanishing-points.

At *c″* and *d″* erect perpendiculars, meeting these, and giving the perspective height of the edges *c* and *d*.

From the upper extremities of these draw lines to the vanishing-points, which will complete the projection.

EXERCISE 33.

The scale to be ¼ inch to the foot; the height of the spectator, 6 feet; his distance, 18 feet.

Put into perspective a cubical figure, 4 feet square at base and 9 feet high, when its left side recedes from the picture-plane at 40°, and its nearest angle is at 6 feet on the left of the spectator.

EXERCISE 34.

Put into perspective the same object when it is at 8 feet on the right of the spectator, and 10 feet within the picture.

Fig. 46.—The subject of this lesson is a square block or plinth, on which rests another square block of smaller size, thus leaving a ledge or step all round.

The height and distance of the spectator having been duly arranged, and the width and position, A B, of the object having been marked, draw lines from A and B to the centre of the picture.

From B draw a line to the point of distance, cutting the line A C in C′.

From C′ draw a horizontal line, cutting the line B C in D.

A C′ B D is then the plan of the plinth.

This figure will be seen to contain one diagonal, B C′. Draw the second, A D.

It is now necessary to draw within this plan the plan of the upper block; that is, to show where the upper block would stand if it penetrated the plinth and touched the ground.

From A mark off E, and from B mark off F, each of the lengths A E and B F being equal to the distance which the plinth projects beyond the upper block; that is, the width of the ledge or step all round.

From E and F draw lines to the centre of the picture, cutting the diagonals in *e g* and *f h* respectively.

Join *e f h g*, and the figure thus formed will be the plan of the upper block.

Now, as the upper block stands back from the plan of the picture, it will be easily understood that the perspective height will be different from the *real* height, and therefore it becomes necessary to erect in the immediate foreground a perpendicular, on which all heights are marked, and from which their apparent heights are obtained. This perpendicular is called the *line of measurement*.

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* See "Practical Geometry Applied to Linear Drawing." Fig. 2 (Vol. I., p. 64).

To obtain this, draw a line from C, passing through the intersection *i* of the diagonals A D, B C′, and meeting the picture-line in L.

At L erect the required perpendicular, of indefinite height.

These preliminaries being settled, erect perpendiculars from each of the angles A, B, C′, D.

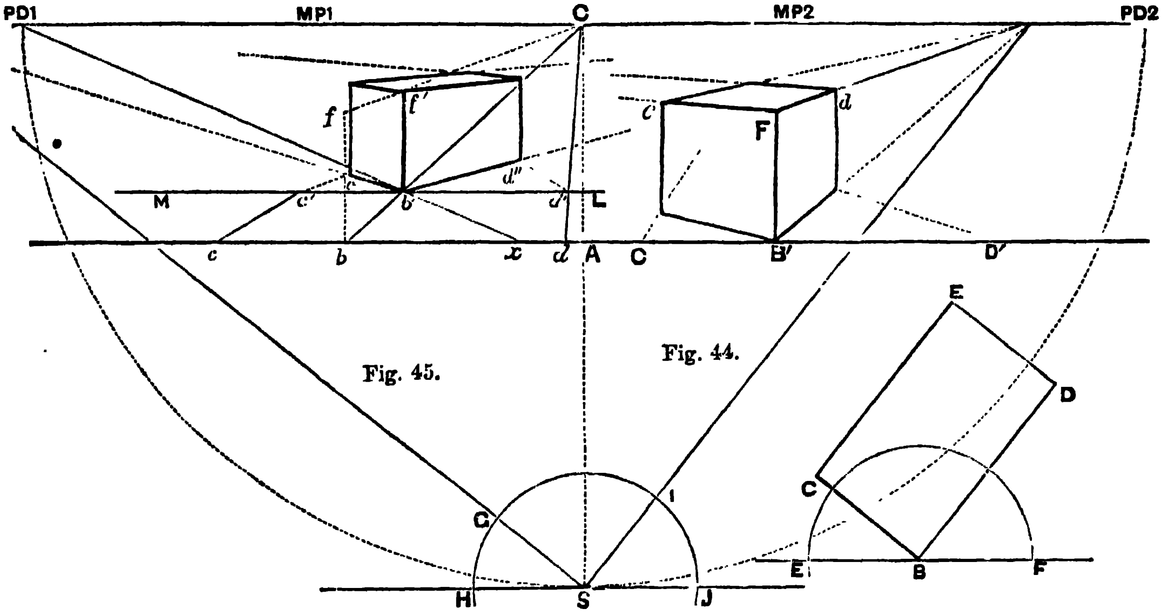


Fig. 45.

Fig. 44.

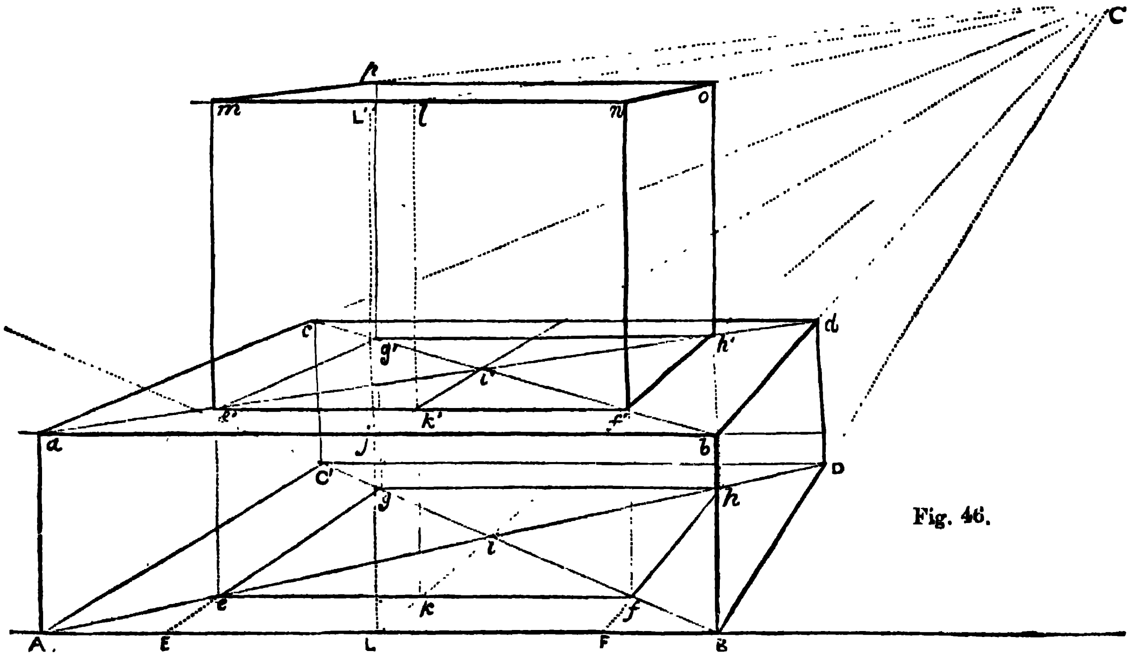


Fig. 46.

On the line of measurement mark off L *j*, the height of the plinth; through *j* draw a horizontal, cutting the perpendiculars A and B in *a* and *b*; the horizontal *a b*, thus obtained, will be the upper edge of the front of the plinth.

From *a* and *b* draw lines to C, cutting the perpendiculars C′, D in *c* and *d*. Join *c d*, which will complete the plinth.

On the upper surface of the plinth draw the diagonals *a d* and *b c*.

From the points *e, f, g, h* (the angles of the inner figure) in the plan erect perpendiculars, cutting the diagonals *a d* and *b c* in *e′, f′, g′, h′*.

Join these points, and from *j* on the line of measurement draw a line to C, cutting the line *e′ f* in *k′*.

Now it will be seen that the line drawn from the centre of the picture, through *i* in the ground-plan, passes through *e f* in *k*, which point is immediately under *k′*. Therefore a perpendicular raised from *k* should, if the work has been correctly done, pass through *k′*, and this line represents the plan or surface of the smaller block.

Now on the line of measurement set off L′, the real height of the upper block, and from L′ draw L′ C, cutting the perpendicular *k k′* in *l*.

Through *l* draw a horizontal, cutting the perpendiculars *e* and *f* in *m* and *n*.

The rectangle *c′ m n f* is then the front of the upper block.

From *m* and *n* draw lines to C, cutting the perpendiculars *g* and *h* in *p* and *o*. Join these points, and the figure will be completed.

From the nature of the lessons which have been already given in this important subject the student will have learnt the necessity of proceeding with zealous care from step to step, so as to insure accuracy in his work. It is better to repeat every measurement twice, if not thrice, before proceeding to work from it by any point or line thus obtained, as a single false step, involving even a very minute error in distance or position, may prove the means of rendering a great deal of otherwise carefully bestowed labour useless, and compelling the learner to cancel the faulty drawing and begin another.

Another point to be insisted on in writing a description of the method adopted in working out any problem or exercise is an accurate and careful rendering of the lines and points of measurement, shown in the figure by letters, and a rigid adherence to the letter or letters by which each point or line is known when once fixed. Although it is not absolutely necessary, it is better always to designate a line by *two* letters, namely, those assigned to the points which are its extremities, an angle as well as a triangle by *three* letters, and a parallelogram or trapezium by *four* letters, taking care in the last-named case that the letters of the corners read in regular order round the figure in either direction, as B, D, F, C, or B, C, E, D, in the plan in Fig. 44, and not B, D, C, E, or B, C, D, E, as is frequently but inaccurately written by students.

SEATS OF INDUSTRY.—XI.

DUNDEE.—I.

BY WILLIAM WATT WEBSTER.

THERE are few towns in Europe that owe their importance and prosperity so largely to the cultivation of one branch of manufacture as the town of Dundee, the chief seat of the linen trade in Scotland, and, although both sides of the Atlantic were to be searched for parallels, it would not be easy to find many instances of towns that have made more rapid progress. How the Scotch linen trade came to be concentrated to so large an extent in Dundee is a question that has often been asked, but never satisfactorily answered. Frequent and persevering efforts were made to establish various industries in the town, previous to the time when the manufacture of the coarser descriptions of linen cloth became the staple trade of the place, but they all sooner or later ended in failure. Linen manufacture is the only industry of any magnitude that has been permanently successful in Dundee, and it seems to have been adopted simply as one among the many experiments that were tried. Commenting on the "wonderful progress" of the linen manufacture in this town, Mr. M'Culloch says, "Something must be ascribed to the convenient situation of the port for obtaining supplies of raw material; and more, perhaps, to the manufacture having been long established in the towns and villages of Strathmore, the Carse of Gowrie, and the northern part of Fife, of which Dundee is the emporium. But these circumstances do not seem adequate to explain the superiority to which she has recently attained in that department; and, however unphilosophical it may seem, we do not really know that we can ascribe it to anything else than a concurrence of fortunate accidents." Of course, the chance theory is no explanation, but merely an ingenious method of stating that our information regarding the early history of the Dundee linen trade is not complete and perfect enough to furnish a solution of the problem. The enterprise of the inhabitants ought, however, to be considered among the causes of the extraordinary prosperity of the town, and a brief sketch of its history and growth will show this influence at work in the periods when its progress was most marked.

The name Dundee is said to be derived from *Don Dei*, a corruption of *Donum Dei*, and to have been conferred on the town in commemoration of the extraordinary escape from shipwreck of Prince David, Earl of Huntingdon, not far from the mouth of the Tay, on his return from the Crusades, in the year 1189. Previous to that date the town was called *Alectum*, or *Ail-lec*, which in the Gaelic tongue signifies "pleasant," or "beautiful." *Taodunum*, the "hill or fort on the Tay," was the name bestowed upon their settlement in this quarter by the Romans, who, it is recorded, were so struck by the resemblance between the river and their own "father Tiber" when they first approached it, that they exclaimed "*Ecce Tiber!*" There is a tradition that about the year 834 a British force having encamped on Tothelbrow, in the parish of Strathmartine, and the Scottish army, under Alpine, having occupied Dundee Law, a hill on the north side of the town, about 525 feet above the level of the Tay, a battle was fought in the intervening plain, which resulted in the defeat of the Scots and the capture and execution of their king. It was not till the accession of William the Lion, in 1165, that Dundee was incorporated as a royal burgh, but it had enjoyed many privileges before that date, and must have been a town of no small consequence. Traces of fortifications have been observed on the summit of Dundee Law, which are believed to have been erected by Edward I., who twice sacked and burned the town, in 1296 and in 1303, and by whom its ancient records were destroyed. It was recovered, however, by Wallace and Bruce, in 1297, and by Bruce in 1313, and at the latter date the old castle was demolished. Dundee was again burned to the ground by the Duke of Lancaster, in 1385, and it suffered a similar fate in the reign of Edward VI., when the English held possession of Brough Tay Castle. George Wishart preached the principles of the Reformation here during the plague, in 1544, from one of the gates of the town, which served to separate the uninfected from the infected, the archway of which is still standing. Though Wishart's teaching and the influence of James Halliburton, one of the earliest and ablest of the Scottish Reformers, and a native of the place, Dundee was the first of all the Scottish towns to renounce Popery, and openly profess the reformed religion. It is worthy of mention that dramatic representations, in which the vices and absurdities of the priests were ridiculed, were among the means resorted to by the earlier Reformers to wean the affections of the people of the town from the Roman Catholic Church. Two brothers of the name of Wedderburn were conspicuous among the writers of these polemical plays, one of whom was vicar of Dundee, and they are also remembered as the authors of "Gude and Godly Ballads," a series of songs devoted to the same cause. A third brother is said to have "turned the tunes and tenors of many profane songs into godly songs and hymns, whereby he stirred up the affections of many;" and it has been suggested that these were the tunes referred to by Burns, as "Dundee's wild warbling measures." But the adhesion of the inhabitants to the solemn league and covenant brought severe disaster to the town, for the Marquis of Montrose, in 1645, burned and plundered it. Dundee, however, suffered still more from Cromwell than it did from Montrose, for its citizens having refused to surrender to his authority, the Dictator sent General Monk against it. A gallant resistance having been made, Monk stormed the town, killed about a thousand soldiers and inhabitants, and afterwards plundered and burned the place. Each soldier in the victorious army had nearly £60 sterling as his share of the booty; but none of them were destined to enjoy any portion of the treasure, for the sixty vessels containing it were totally wrecked on their way to England. This was the last great disaster that Dundee sustained, and since that date it has made steady progress, nor has its subsequent history been marked by any extraordinary event.

It is not known when the linen manufacture was introduced into Dundee, but it was doubtless carried on there at a very remote period, although only on a small scale. Several highly interesting references are made to linen in ancient Scottish records, and it would appear that the dressing, spinning, and weaving of flax was a part of the general domestic work of the people for many centuries. It is mentioned that at the battle of Bannockburn, in 1314, "carters, wainmen, lackeys, and women put on shirts, smocks, and other white linens, aloft upon their usual garments, and bound towels and napkins on their spears, staves, etc." The rental lists of the Marquis of Huntly show that in 1600 rent was sometimes paid in linen; and an Englishman, who made a tour in the Highlands of Scotland about the year 1618, states that the master of the house, whether laird, farmer, or cottar, "will wear no shirt but of the flax that grows on his own ground, or of his wife's, daughters', or servants' spinning."

Towards the close of the sixteenth century, linen goods were among the principal exports from Scotland, and were sent both to England and to foreign countries. Between 10,000 and 11,000 persons were said to have been employed in Scotland about this time in making linen for the English market. Unfortunately, the Scottish Parliament passed a law prohibiting the importation of woollen goods from England, and this policy led to the prohibition of Scotch linen by the English Parliament, which for a time completely ruined the linen trade of Scotland. In 1686 the Scottish Parliament passed a curious law, entitled an "Act for Burying in Scotch Linen," in which it was decreed that "hereafter no corpse of any persons whatsoever shall be buried in any shirt, sheets, or anything else, except in plain linen or cloth of hards, made and spun within the kingdom, without lace or points." The duty of receiving and recording certificates that bodies had been buried as directed devolved on the parish minister, and severe penalties attached to breaches of the Act. In 1693 another Act was passed, "anent right measuring and making of linen cloth," and ordaining that seals be put on every piece or half-piece, as a proof that it was the right length, breadth, and quality. The Union gave a great impetus to the linen trade of Scotland, the duties on linen goods exported to England having then been abolished, and the colonial markets opened for Scotch manufactures. At this period some 1,500,000 yards of the coarser kinds of linen cloth were annually manufactured in Scotland; and in 1720 the linens exported to England alone were valued at £200,000. Seven years later a board was established to promote and encourage the manufactures of Scotland, which had a powerful influence in developing the linen manufactures of Dundee. The incorporation of the British Linen Company, at Edinburgh, in 1746, was also a great event in the history of the Scotch linen trade. This company imported flax, linseed, and potash, which were sold on credit to respectable manufacturers, and it bought back the yarn and linen they made at fair prices. The British Linen Company also advanced money to the manufacturers on exceedingly reasonable terms, the original subscribers not having entered upon the enterprise with the view of making gain, but simply in order to further the welfare of the linen trade.

The linens manufactured in Scotland were described by a writer in the "Gentleman's Magazine," in 1742, as "the poorest and meanest;" but at that time Dundee was more celebrated for its "plaiding," a coarse woollen cloth, than for its linen. This was one of the trades that flourished for a season in the town. It was about the year 1747 that the manufacture of the linen cloth known as Osnaburg became the staple trade of Forfarshire, and especially of Dundee. In the year 1789 no less than 3,181,990 yards of coarse linen cloth, valued at £80,587, were manufactured and stamped for sale in the parish of Dundee; and 700,000 yards of sail-cloth, considered superior to that produced at Belfast, and estimated at a value of £32,000, were made within the precincts of the town. The spinning of coloured sewing thread was also at this time, and had for several years previous been an important branch of industry in the place, it having at one period been prosecuted by seven different companies or firms, maintaining an aggregate of 66 twisting-mills, employing some 1,340 spinners, and turning out annually about 270,000 pounds of thread, valued at upwards of £33,500. In 1790 a spirited attempt was made to add the spinning of cotton to the manufactures of Dundee. Seven cotton-spinning companies were started within a short time, and continued in operation for some years, but never succeeded in making the trade remunerative. Till the year 1790 all the yarn used in Dundee was spun by hand, and chiefly by people in the surrounding country districts, and the larger portion of it continued to be supplied in this way till about 1830, when spinning-machinery came into general use. A mill for spinning yarn by machinery driven by water power, erected in 1790, by Messrs. Ivory and Co., at Kinnettles, Forfarshire, was an important improvement, and three years afterwards a still more important, though not immediately successful, experiment was made, when Messrs. Fairweather and Marr built a small spinning-mill at Chapelside, the machinery of which was propelled by a ten-horse-power steam-engine. This latter mill, and another steam-power mill started shortly after it, were kept working for some time, and then stopped, but only to resume again after an interval. There were 5 steam spinning-mills, with an aggregate of 60 horse-power, and 2,000 spindles, in operation in the town of Dundee in 1798, the largest of which was the Bell Mill, erected at a cost of £17,000. The wars of Napoleon, in the early years of the present century, paralysed the linen trade of Scotland, and in 1811 there were only two spinning-mills at work in Dundee; but after the battle of Waterloo the trade revived, and by the year 1822 there were no fewer than 17 steam spinning-mills, containing 7,944 spindles, driven by engines with an aggregate of 178 horse-power, and employing about 2,000 persons, in operation in the town, while in its immediate neighbourhood there were 82 spinning-mills, containing 6,978 spindles, at work. Ten years later the steam spinning-mills in Dundee and the surrounding district were driven by engines representing a total of 800 horse-power, and employed about 3,000 persons, while the yearly consumption of flax was 15,600 tons, and the capital invested in machinery amounted to £240,000. By 1846 the number of steam spinning-mills had increased to 36, containing 71,670 spindles, and driven by engines with an aggregate motive power equal to 1,242 horses. From "Dawson's Abridged Statistical History of Scotland," published in 1853, we learn that there were in 1850 in the town and the immediate vicinity of Dundee "47 spinning-mills, with steam-engines of an aggregate of 2,075 horse-power, and 8 power-loom factories, possessing 235 horse-power," and that those establishments employed in the various occupations 3,240 males and 8,142 females. "It has been ascertained," this account continues, "that the money wages distributed among this large body of individuals amounts to about £3,900 per week; the payment to the male operatives being on the average 9s. 6d., and to females 6s. weekly. Besides the power-loom factories, the town possesses 62 establishments of one kind or other using hand labour; and in these there are 4,200 looms. Add to these, 10 establishments for finishing, calendering, and packing the cloth which is produced, and we have an idea of the vigour with which the linen trade of Dundee is conducted." Since that period from 600 to 700 additional power-looms have been started. A few statistics relating to the linen and jute trade in 1867 will illustrate the astonishing progress made by the Dundee manufacturers between 1850 and that date; and since 1867 the trade has been still further developed. It was estimated that in 1867 the capital invested in factories for the spinning and manufacture of flax and jute in the town of Dundee amounted to £2,500,000, in the district to £2,200,000, and in other parts of Scotland to £1,000,000; giving a total of £5,700,000. The yarn spun in the town during the same year was calculated to amount to 31,000,000 spindles, representing a value of £3,487,500; and in the surrounding district 29,000,000 spindles were produced, valued at £3,262,500, giving a total for Dundee and its dependencies of 60,000,000 spindles, representing £6,750,000. The cloth manufactured by the 8,000 power-looms in the same year, calculated at an average of 200 yards per week for each loom, would amount to about 83,200,000 yards, or 47,272 miles. Mr. Warden, the author of "The Linen Trade," states that about 50,000 persons are employed in the linen and jute trade of Dundee. It was in 1821 that the first attempt was made to introduce power-looms in Dundee, but the experiment was not successful till fifteen years later. Messrs. William Baxter and Son built a mill at Lower Dens, intended for 90 power-looms, but they did not at that time carry out their design. In an account of Dundee written in 1833, it is stated that "power-looms have not been employed here, or, at least, not to any advantage, and they are understood to be entirely laid aside." The first power-loom factory erected in Dundee was built in 1836, at Upper Dens, by Messrs. William Baxter and Son, and soon after three others were erected, but a considerable time elapsed before any increase took place. It was only gradually that the power-loom came to supersede the hand-loom, and the latter has not even now been entirely discontinued.

PRINCIPLES OF DESIGN.—XV.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

WALL DECORATION

In this chapter we must devote ourselves to the consideration of wall decoration, or to the manner in which ornament should be applied to walls with the view of rendering them decorative.

It will appear absurd to say that all ornament that is applied to a wall should be such as will render the wall more beautiful than it would be without it; but this statement is needed, for I have seen many walls ornamented in such a manner, that they would have looked much better if they had been perfectly plain, and simply washed over with a tint of colour.

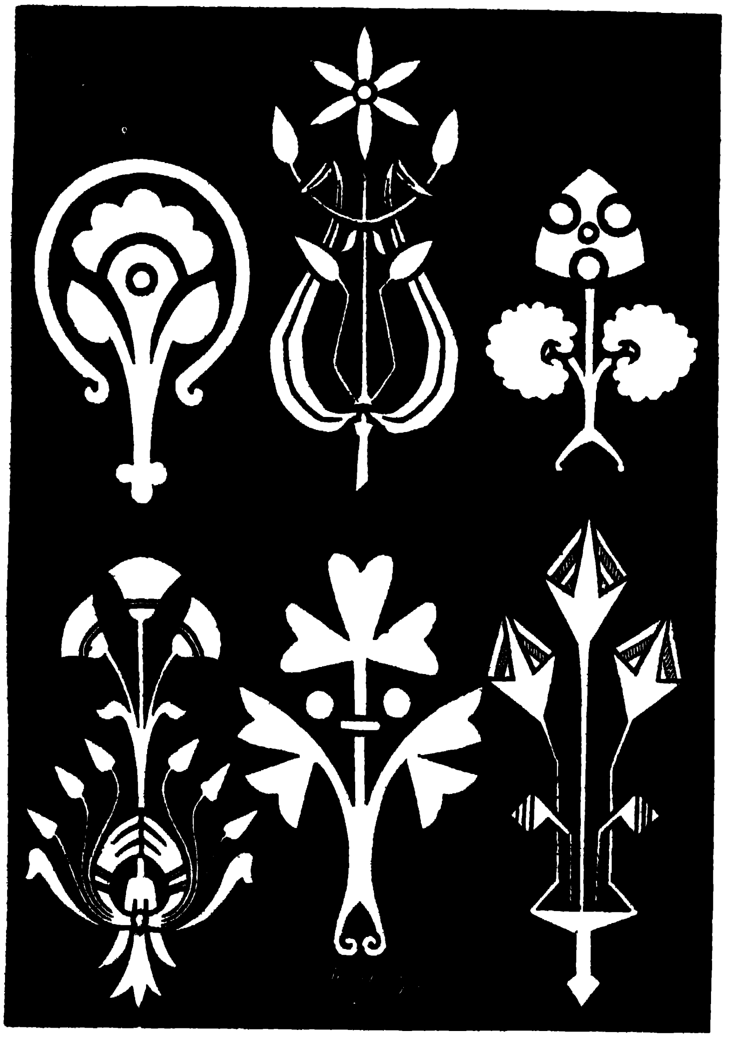
To ornament is to beautify. /To decorate is to ornament. But a surface cannot be beautified unless the forms which are drawn upon it are graceful, or bold, or vigorous, or true, and unless the colours applied to it are harmonious. Yet how many walls do we meet with even in good houses—walls of corridors, walls of staircases, walls of dining-rooms, walls of libraries, and, indeed, walls of every kind of room—which are rendered offensive, rather than pleasing, by the decorations which they bear.

A wall may look well without decoration strictly so called, and this statement leads me to notice the various ways in which walls may be treated with the view of rendering them beautiful.

A wall may be simply tinted either with distemper colour, or oil colour "flatted." Distemper colour gives the best effect, and is much the cheapest, but it is not at all durable. Every mark will show upon it; if rubbed, it is marked; and it cannot be washed. Oil colour when flatted makes a nice wall, whether "stippled" or plain, and is both durable and washable. An entire wall should never be varnished.

I say that a wall can look well even if not decorated. Let me give one or two instances; but, perhaps, I had better give treatments for the entire room, including the ceiling, and not for the wall simply.

A good effect of a very plain and inexpensive character would be produced by having a black skirting, a cream-colour wall (this colour to be made of middle chrome yellow and white, and to resemble in depth the best pure cream), a cornice coloured with pale blue of greyish tint, with deep blue, white, and a slight line of red, and a ceiling of blue of almost any depth. The ceiling colour to be pure French ultramarine, or this ultramarine mixed with white and a touch of raw umber, and the cornice blues to be made in the same way. The red in the cornice to be deep vermilion if very narrow (one-sixteenth of an inch), or carmine if broad.*



A room of a slightly more decorative character would be produced by making the lower three feet of the wall of a different colour (by forming a dado) from the upper part of the wall: thus, if the other parts of the room were coloured as in the example just given, the lower three feet might be red (vermilion toned to a rich Indian red with ultramarine blue) or chocolate (purple brown and white, with a little orange chrome); this lower portion of the wall being separated from the upper cream-coloured portion by a line of black an inch broad, or better by a double line, the upper line being an inch broad, and the lower line three-eighths of an inch, the lines being separated from each other by five-eighths of the red or chocolate.

I like the formation of a dado, for it affords an opportunity of giving apparent stability to the wall by making its lower portion dark; and furniture is invariably much improved by being seen against a dark background. The occupants of a room always look better when viewed in conjunction with a dark background, and ladies' dresses certainly do.

The dark dado gives the desired background without rendering it necessary that the entire wall be dark. If the furniture be mahogany, it will be wonderfully improved by being placed against a chocolate wall.

The dado of a room need not be plain; indeed, it may be enriched to any extent. It may be plain with a bordering separating it from the wall, such as Figs. 43, 44, or 45; or it may have a simple flower regularly dispersed over it; or it may be covered with a geometrical repeating pattern, in either of which case it would have a border; or it may be enriched with a special designed piece of ornament, as Fig. 46. This particular pattern should not, however, be enlarged to a height of more than twenty to twenty-four inches; but if of this width, and above a skirting of twelve or fifteen inches, it would look well.

I have designed two or three narrow dado papers for Messrs. Wylie and Lockhead of Glasgow, which are about eighteen inches broad, and are printed in the direction of the length of the paper, so as to save unnecessary joins.

If the dado is enriched with ornament, and the cornice is coloured, and a pattern goes all over the ceiling, the walls can well be plain, but they may be covered with a simple "powdering" as the patterns in Fig. 47, if these are in soft colours.

A good room would be produced by pattern Fig. 48 being on the ceiling in dark blue and cream colour, by the cornice being coloured with a prevalence of dark blue, the walls being cream-colour down to the dado; the border separating the dado from the wall being black ornament on a dull orange colour, and by the dado being chocolate with a black rosette upon it; the skirting boards being bright black. The dado may or may not be varnished; the upper part of the wall can only be "dead" (not varnished, dull). If the room is high a bordering may run round the upper portion of the wall, about three to four inches below the cornice; such a border as Fig. 49, may be employed in dull orange and chocolate.

A citrine wall comes well with a deep blue, or blue and white ceiling, if blue prevails in the cornice, and this wall may have a dark blue (ultramarine and black) dado, or a rich maroon dado (brown lake). If the blue dado is employed the skirting should be indigo, which when varnished and seen in conjunction with the blue, will appear as black as jet.

Walls are usually papered in middle-class houses. I must not object to this universal custom; but I do say, try to avoid showing the joinings. In all cases where possible, cut the paper to the pattern, and not in straight lines, for straight joinings are very objectionable. If you use paper for walls, use it artistically, and not as so much paper. Let a dado be formed of one paper, the dado bordering (dado rail) of a suitable paper bordering; the upper part of the wall being covered by another paper of simple and just design, and of such colour as shall harmonise with the dado. Proceed as an artist, and not as a mere workman. Think out an ornamental scheme, and then try to realise the desired effect. Avoid all papers in which huge bunches of flowers and animals or the human figure are depicted. The best for all purposes are those of a simple geometrical pattern, or in which designs similar to those in Fig. 47 are "powdered" or placed at regular intervals over a plain ground.

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* In some parts of the country it is customary to wash the cornice over with quick-lime. If this has been done, the lime must be carefully removed, for lime will turn carmine black.

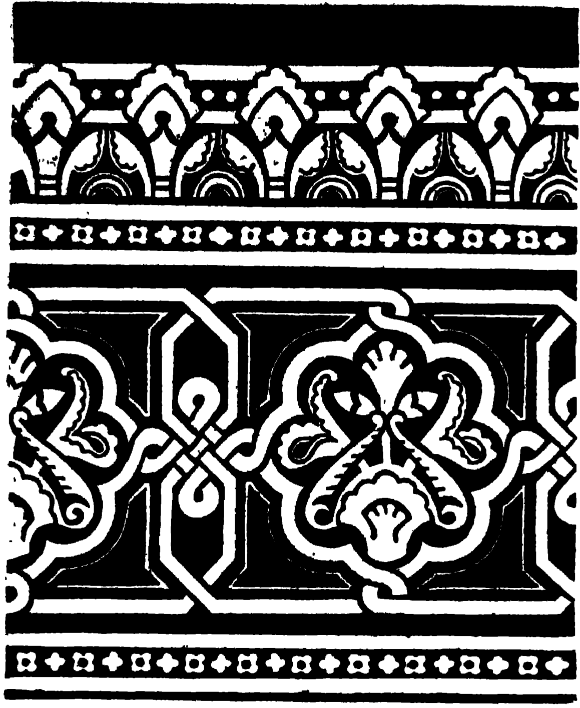


Fig. 46.

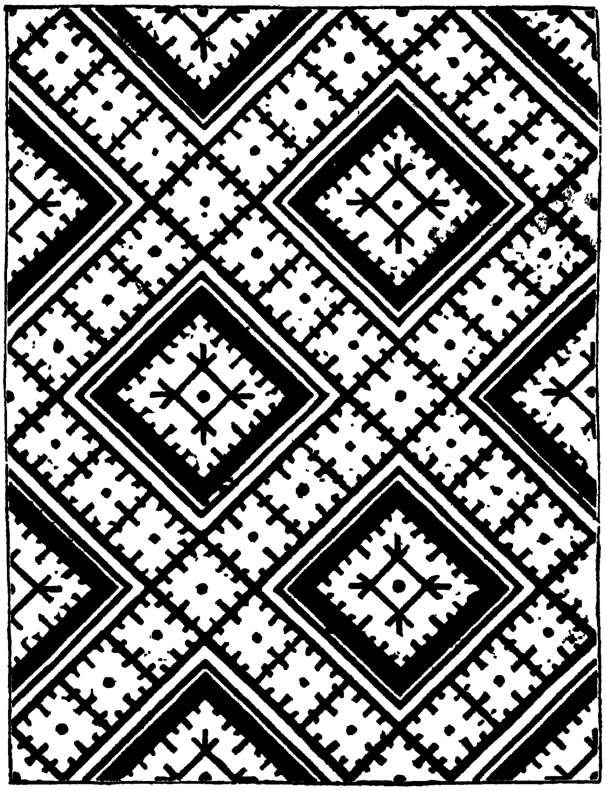


Fig. 48.

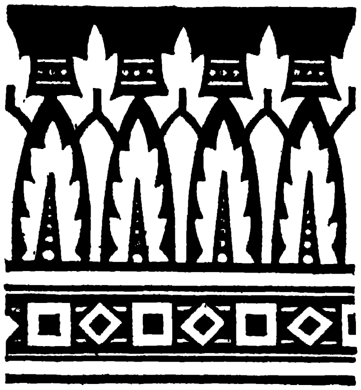


Fig. 43.

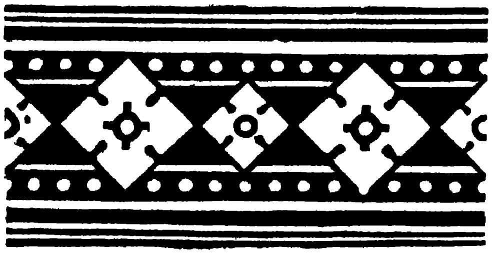


Fig. 44.

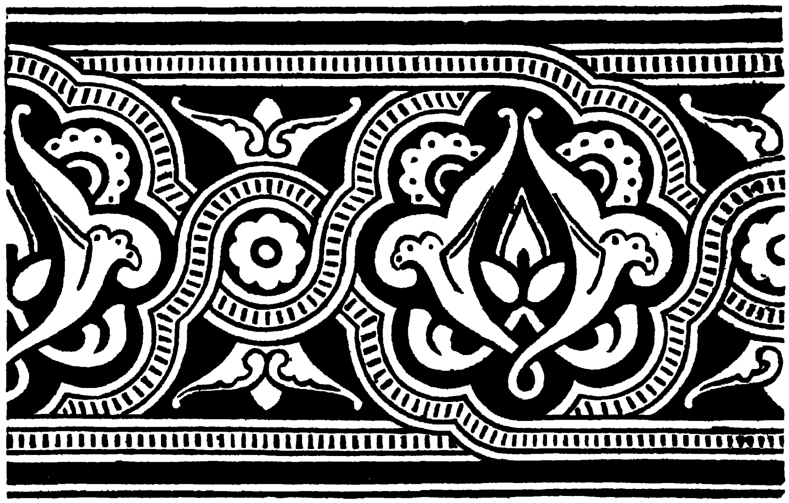
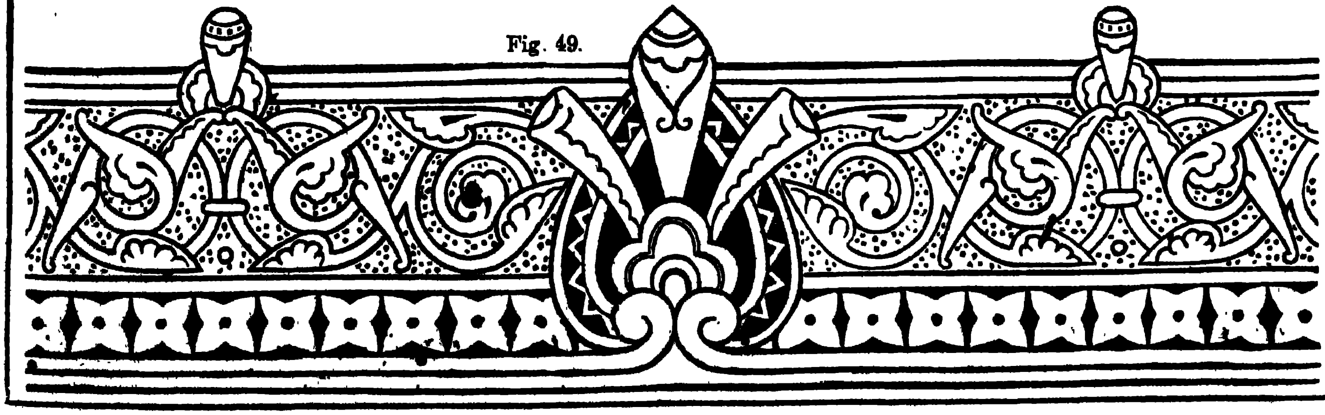


Fig. 45.

Fig. 49.



COLOUR.—XI.

By Professor Church, Royal Agricultural College, Cirencester.

SURFACE AND STRUCTURE MODIFY COLOUR—COLOURS OF METALS—DAMASCENING AND PLATING—ENAMELLING ON GOLD AND SILVER—LACQUERING—COLOURS OF GEMS—COLOURED MARBLES.

The colour of objects is influenced not only by the nature of the light by which they are illuminated, but also by their own peculiarities of texture, structure, and surface. The coloured light reflected from satin is different from that of velvet, though the silk used in the manufacture of these fabrics may have been dyed in the same bath. In explaining modifications of colour produced by texture, etc., we shall select a series of illustrative examples from the mineral, vegetable, and animal kingdoms. We shall then proceed to explain their colour-peculiarities, and the manner in which these may be utilised, in decorative art more particularly.

Metallic colours first claim our attention. Polished metals are distinguished for their intense power of reflecting light, and for an almost complete opacity. An intense reflection of light is also observed with other than metallic surfaces, such, for instance, as the neck of the peacock, and that beautiful chemical salt, the magnesium platinocyanide. But there are some points in which these lustrous colours differ from those of the true metals. We have alluded to this subject in Lesson I., and may here proceed to apply the principles of absorption and reflection of colour there laid down to the special case of metallic colours. Now it will be allowed that, under ordinary circumstances, metals do not appear highly coloured, though their brilliancy is often intense. The angle of incidence of the light has much to do with this. When we take a polished and level plate of gold or copper, and look along its surface, we shall see it appear very brilliant, but nearly white. In such a case, the rays of light which illuminate it almost graze the surface, making an angle of nearly 180° with the reflected rays that reach the eye. But let this angle be reduced to one of a few degrees only, then the proper colour of the metal will be conspicuous. It may be still further developed and enriched by repeated reflections at a small angle of incidence. Fig. 19 illustrates the mode in which a beam of light may become in this way more highly saturated with colour by numerous reflections from two polished surfaces of metal. From this cause chased gold and "granulated" gold appear of a far richer colour than burnished gold. And by so shaping the grooves or lines of chasing upon any piece of coloured metal, that repeated reflections at small angles of incidence occur in them, very rich colour-effects may be produced. The splendid colours inside gold or gilt goblets arise from this cause. Many metals which lack distinctive colour under common conditions may thus be made to develop it. Yet the colour thus produced not only changes in tone or saturation as it becomes enriched, but its quality is also modified. Thus copper may be made to yield ultimately a nearly pure or monochromatic red light by repeated reflections. The colour is more distinct, it is purer; but there is less light.

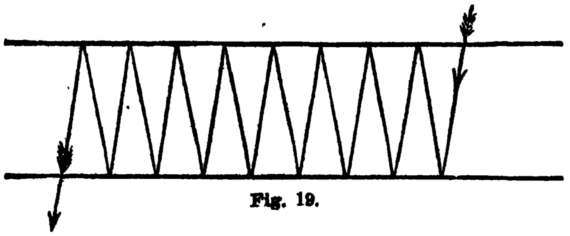


Fig. 19.

The colour of a pure metal may be greatly altered by alloying it, even slightly, with another. Thus, gold 22 parts, with 2 parts of silver, produces a metal of a greenish colour, which may be rendered still more decided by a small further addition of silver. Copper, on the other hand, to the extent of 10 or 12 per cent., reddens gold; while a small admixture of both copper and silver does not materially affect its colour, though it makes it rather paler. A large proportion of silver, varying from 20 to 50 per cent., produces electrum, some specimens of which, where the silver exists in nearly equal proportion with the gold, are almost white. Ancient and modern coins, as well as jewellery, furnish interesting examples of the variations in the colour of gold produced by alloy. The old Roman gold coins, with less than 1 per cent. of alloy, show the rich characteristic orange tint of the pure metal; while in a handful of modern sovereigns the yellowish-orange ones indicate the presence in the alloy of copper and silver; the greenish ones indicate silver alone, and the reddish ones copper alone. Slight as these differences of colour would appear did they belong to ordinary pigments, yet, in the case of the metals, the intensity of their reflection enables us to use with effect coloured varieties of gold in ornamental jewellery. Gold, if not alloyed very much (not more than 9 parts in 24), may be made to assume its proper colour by a process of "pickling" or "colouring." Gold articles plunged when warm into nitric acid lose a portion of their superficial alloy, be it copper or silver, the pure metal being left with a somewhat *matt*, or dead surface, and a rich orange colour. Or a mixture of equal parts of borax, nitre, and sal-ammoniac may be made, ground into fine powder, mixed with a little water, and applied as a thin coating to the metal. The metallic object is then heated till a faint discolouration appears on the coating; afterwards, the paste being washed off, the pure gold film will appear beneath. With a film thus prepared, and with some of those films which are obtained by electro-metallurgical processes, the brilliancy of the metallic reflection is much impaired, though its characteristic colour may remain. This alteration arises from the loss of continuity of the metallic surface. Silver, in fact, may be so precipitated from a solution as to present a surface almost indistinguishable from a sheet of cream-wove white paper; and gold may be obtained by similar processes in a state which presents a close resemblance to yellow ochre. Some of the most beautiful effects in the decorative employment of metals may be obtained by the partial polishing or burnishing with an agate or steel tool, of such matt or dead surfaces as these. When silver is deposited by Liebig's silvering liquid on glass, it may be made to assume a most perfect, or "black," lustre, and is then applicable for use in mirrors or in the reflectors of telescopes. Here the continuity of surface is practically perfect.

The delicate and subtle contrasts between metallic colours has led to the association of two or more metals in several kinds of decorative work. We have already referred to the varieties of coloured gold. In jewellery red gold may be used for flowers, with white gold or electrum; green gold may be employed for leaves; while the ornamental spray itself may be laid upon a chased or granulated surface of pure orange-coloured gold. By the process of parcel-gilding on silver, a more decided difference of colour may be secured; while the methods of metallic inlaying and damascening enable us to obtain the more marked contrasts between iron and gold and iron and silver. In these latter cases we have not only a considerable difference of colour between the two metals, but a very distinct difference in reflecting power. Iron or steel covered, by an easy chemical method, with a film of platinum, is preserved from corrosion, and still furnishes an excellent combination with silver or gold, or with both of these metals, as inlays.

Before giving a list of the colours of a few metals in their pure and unalloyed state, we may remark that other metals besides gold are remarkably modified in hue by the presence of alloy. Perhaps copper shows this effect more commonly and more distinctly than any other. An alloy of 85 parts of copper with 15 parts of tin, or with 15 parts of a mixture of tin and zinc, constitutes a mixed metal of a rich yellow colour, the pink colour of the copper being then much altered. So 5 parts of the bluish-white metal aluminium will similarly modify the colour of 95 parts of copper, an effect seen in the so-called aluminium gold, or aluminium bronze, which is thus constituted. If the copper be mixed with tin in the proportion of 70 of the former metal to 30 of the latter, then the alloy is no longer yellow, but greyish-white, forming what is known as *speculum metal*.

The colours of some of the metals, in a few cases ascertained and determined by two or more reflections, are here given:—

Copper	*red.*	Silver	*orange-yellow.*
Gold	*orange.*	Sodium	*rosy pink.*
Lead	*bluish-grey.*	Steel	*neutral grey.*
Mercury	*slaty-grey.*	Tin	*greyish-yellow.*
Potassium . . .	*lavender-grey.*	Zinc	

There is one remarkable and important property enjoyed by metals, and particularly by gold, of at once harmonising with and setting off ordinary coloured materials. Two instances of such a use of gold will occur to every one—the gilt frame of a picture, and the gold threads in embroidery. Gold, in fact, is removed from the series of ordinary paints and dyes by the intensity of its metallic lustre, and so combines into agreeable assortments with all colours, even with those with which yellow and orange pigments do not associate well. In a picture-frame this peculiarity of its metallic lustre prevents its yellow colour from interfering with the similar hues of the picture, while its colour being luminous and "near," gives the idea of some degree of distance to the picture itself. We seem to look through an opening into the scene represented.

Gold, and other metals as well, may have their lustre made use of as a brilliant background for the development of colour. A transparent film of some sort is often placed upon metals, and when this film is coloured, such part of the light as escapes reflection at its surface passes through it, is reflected from the metal behind, and again passes outwards, leaving the film strongly tinctured with its colour. Films of this kind are of two sorts, one kind belonging to the vitreous or glassy series of materials, and the other being resinous, that is, essentially similar to a varnish. These transparent films are applied to metals for three purposes—to protect the surface, to cause an inferior metal to assume the aspect of a more precious one, and to produce certain colour-effects not otherwise attainable. Silver, when varnished with white lac, loses some of its brilliancy, but is no longer liable to tarnish. Iron and brass may be protected from corrosion, and improved in appearance, by a lacquer in which the red resin known as *dragons' blood* is an ingredient. With this preparation, silver assumes something of the rich aspect of gold, and iron resembles bronze. Resinous substances may be applied to metals either in the form of varnishes—that is, of solutions which dry and leave a continuous film or coating of the resins they contain—or by means of fusion. In the latter case the finely-powdered resin may be introduced in a pasty form mixed with a little water into the grooves, etc., prepared to receive it, and then heated to the temperature necessary to produce fusion. True translucid enamels of the vitreous class, on the other hand, require a much higher temperature than the resin, and yield far superior and more varied results. They consist essentially of different kinds of glass, coloured suitably with metallic oxides. Blue enamels thus contain cobalt; puce and violet enamels are furnished by manganese; grass green by chromium sesquioxide, and so forth. Such enamels appear on silver of their proper colour, but on gold the hue of the metallic background produces a change of colour, sometimes advantageous, sometimes the contrary. But as the colour of gold may be greatly modified by a little, it is easy to select or prepare a quality of gold suitable for the several coloured enamels in use. The following list gives the most appropriate metals for a few colours:—

Green.—Gold of 20 carats with 4 carats silver alloy.

Red.—Gold of 22 with 2 carats copper, or a mixed alloy.

Violet, rose, white, yellow.—Silver, or, less suitably, white electrum.

Puce.—Electrum of 16 carats gold, 6 carats silver, or gold 20 carats fine.

Brown.—Gold of 20 to 22 carats.

The subject of translucid enamels naturally leads us to the consideration of gems and glass. It ought scarcely to be necessary to vindicate for the natural precious stones a very high position amongst decorative coloured materials. Besides the hardness of the more esteemed sorts of jewels, they present beauties and singularities of colour and optical effect which are, to a great extent, quite inimitable by artificial methods. Yet amongst a certain clique of artists and amateurs it has become the fashion to depreciate their excellence, and, further, to insist upon their being cut, if used at all, in a way which is usually fatal to the development of those qualities upon which the beauty of precious stones depends. This method is known as the cutting *en cabochon* or "tallow-topped," and is applicable or appropriate, as a rule, only to those stones which are not perfectly transparent—opals, cats'-eyes, chrysoprases, etc. When applied to transparent gems, it prevents the full play of light and colour proper to them, internal reflection is imperfect, and the marvellous dispersive power often present does not show its effect in producing the so-called *fire* of the stone. Analysed with a prism, the colour of gems is often found to differ from that of the nearest approach in artificial "paste"—that is, glass—that can be manufactured to represent them. Then, too, gems often exhibit peculiar optical properties which no fused artificial substances can possess. The minute internal fissures, to which the splendid play of colours in the precious opal of Hungary and Mexico is due, cannot be imitated, though there is another mineral, *sphene*, which possesses this remarkable quality in a high degree. The opal is seen best upon a black or dark-blue background of enamel, and is still further enhanced in beauty by a border of small diamonds, which form a delicate yet effective contrast, through their perfect transparency and purity, and their almost metallic lustre, with the milkiness and variegation of the opal. The stones known as star-stones have also optical peculiarities, which are quite inimitable. These gems are essentially crystallised alumina, and are known as star or asterias rubies or sapphires, according to their colour; they are translucent only, and owe their beauty to a peculiarity of their minute crystalline structure. This is revealed when one of these crystals is cut across its principal axis, and left with its top *en cabochon*. Then a six-rayed star makes its appearance, best seen in sunlight, or by the light of a small brilliant flame, or in the focus of a condensing lens. It is due to the symmetrically disposed *layers* of which the crystal is built up. The less transparent varieties of red garnet, when cut as carbuncles, occasionally show a star, but it has only four rays, owing to the simpler crystalline structure of the stone in this case. Among other *chatoyant* stones with a play of light upon or in them, the moonstone, a species of nearly colourless and transparent felspar, is one of the most familiar. Its light is more diffused than that of the star-stones, and has a pearly whiteness. Moonstones may be very effectively combined with dark-coloured clear amethysts, the contrast being not only of colour but of lustre. The stones called cats'-eyes are of two species: one of them, the more precious, is yellow or yellowish-green, hard, and shows a pale bluish line of light when properly cut; this is due wholly to the optical structure of the crystal itself. But in the commoner variety we merely have quartz penetrated with fine fibres of asbestos, which catch and reflect the light. There is one peculiarity of precious stones which we cannot pass over, a property known as *dichroism*. A crystal which is greenish in one direction may appear rose-pink when seen in another. A ray of light is affected differently according to the direction in which it passes through the crystal. The tourmaline is an excellent example of this, a grass-green specimen of this stone appearing dark brown or even black when viewed along the principal axis of the crystal instead of across it. This, again, is a quality of some natural gems which cannot be imitated exactly in artificial mixtures.

We may here find occasion to introduce a word or two concerning the commoner sorts of ornamental and coloured minerals, ranging from agates down to tinted building stones. There are two points of special importance connected with such materials. One of these points is the undesirability of mixing natural with artificial materials in walls and pavements. It is very difficult to combine satisfactorily tiles and marbles. There is a faint approach to translucency in many marbles, which the dull, dry, opaque surface of unglazed tiles contrasts unpleasantly with, and glazed tiles are coarsely artificial in their gloss. Then, again, we have, in the second place, to remind our readers that marbles with natural veinings and mottlings of colour do not allow of sculptured ornament. Your surface decoration in relief will interfere with Nature's prior decoration in colour. The wildness and almost infinite variations of the natural tones of brown in a piece of Derbyshire alabaster are broken up when its surface is diapered with a conventional carved ornament—the natural picturesqueness and the artificial are incongruous. A surface in a tessera of mottled or veined marble, or a pillar, displays its beauties, but in a sculptured capital of the same material they are disfigured, while the light and shade of the ornamental design do not come out properly in the variegated material.

There still remain for study among mineral products glass, porcelain, and pottery. Opalescence and iridescence, as well as several other peculiarities influencing their colour-effect, are common in a measure to some kinds of all these artificial products, and we may, therefore, group them together for consideration in the next lesson.

TECHNICAL DRAWING.—XXXIV.

DRAWING FOR MACHINISTS.

WHITWORTH'S 15-INCH SLIDE-LATHE.

Fig. 344 (*a*, *b*) represents the headstock, slide-rest, and part of lathe-bed in elevation.

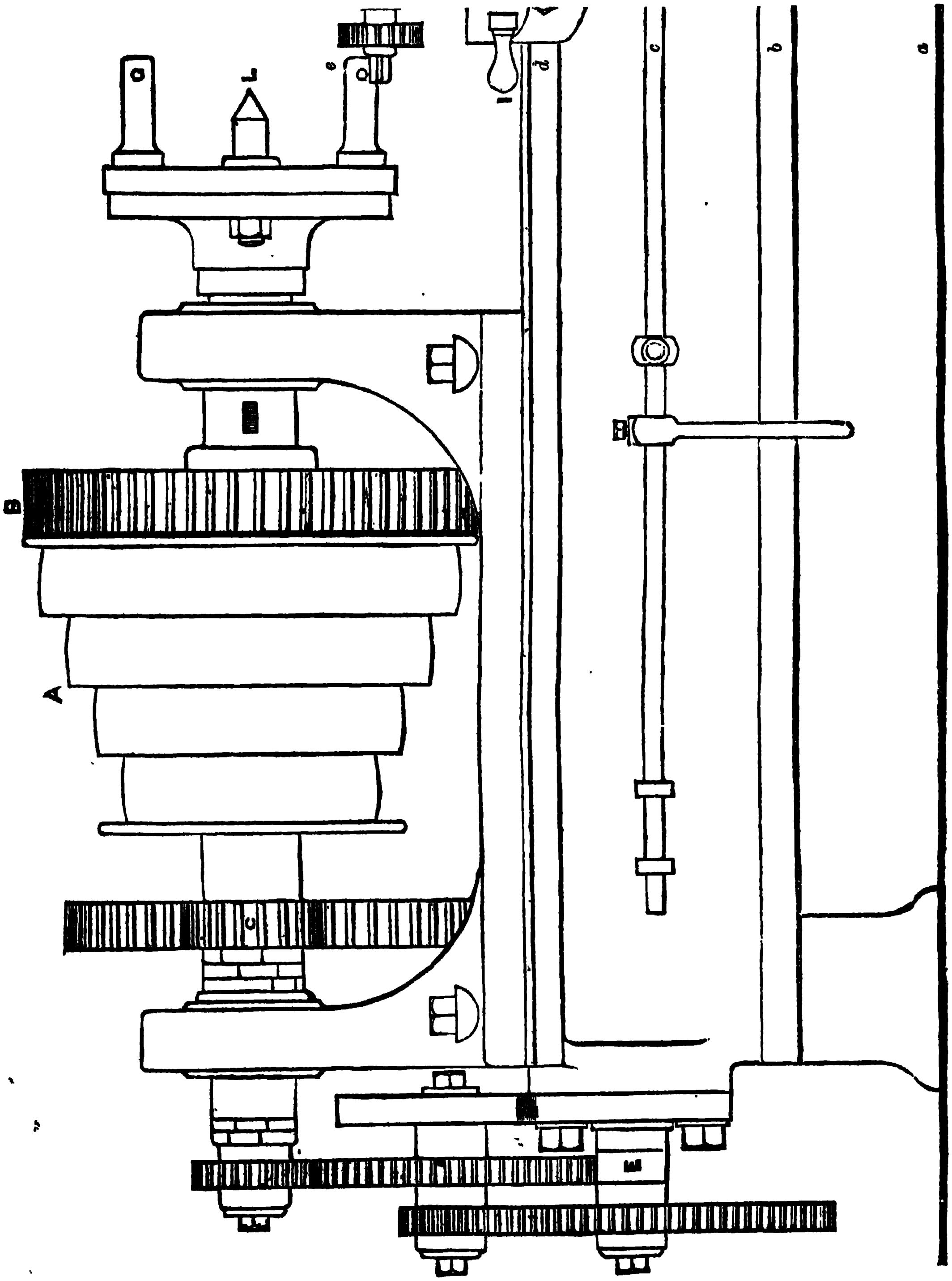


Fig. 344 (*a*).

*** Owing to the great length of Fig. 344 it has been necessary to show it in two parts. The junction of the portions of the figure, as shown in the two parts marked Fig. 344 (*a*), 344 (*b*), is sufficiently indicated by the letters *a*, *b*, *c*, *d*, *e* in each, and the connection of the two parts of the machine thus unavoidably separated is shown by the repetition of the spur-wheel in each portion.

The use of a lathe is to turn iron or other materials into a circular shape, and it does this by causing the object held between its centres, L L (Fig. 344 [*a*]), to rotate against a cutter, F, held in the rest, G (Fig. 344 [*b*]. While the object is in motion the cutter is made to slide along the lathe-bed, and so come against new uncut portions of the object at every revolution, and thus, by continually removing the outer irregular surface, a cylindrical form is given to it.

On the countershaft (Fig. 345) there are two sets of pulleys, A, B, B and A′, B′, B′, each driven by separate straps from the main shaft. The sets A and A′ run in opposite directions, the former for driving the lathe, and the latter for reversing it; and for this purpose it is driven by a crossed strap. The pulleys B, B, B′, B′ are all loose upon the shaft, and the strap-forks, D and D′, can be moved by a vertical rod (not shown), or by the horizontal bar in front of lathe-bed, as shown by Figs. 344 and 347, which will be given in the next lesson.

Both straps are on loose pulleys, as the forks are arranged in the drawing. But if they be moved to the right, then one will be on the fast pulley, A, and the other on a loose pulley, B′: consequently, the lathe will run in its proper forward direction.

By moving the forks to the left hand, the crossed strap drives the pulley A′, and thus reverses the lathe. This arrangement of pulleys is necessary for cutting screws, so as to run the tool back without changing the position of the threads of the guide-screw relatively to those of the screw which is being cut by the lathe.

By putting the strap on any cone of the pulley C leading to the lathe, variations in speed may be readily obtained.

In order to make the machinery self-preserving from accident, a stop is fixed on the bar in front of the lathe which moves the strap-forks, so that a stud upon the slide-rest shall move the strap upon a loose pulley, and stop the lathe before any damage can take place from contact between the slide-rest and fixed headstock by the guide-screw overwinding.

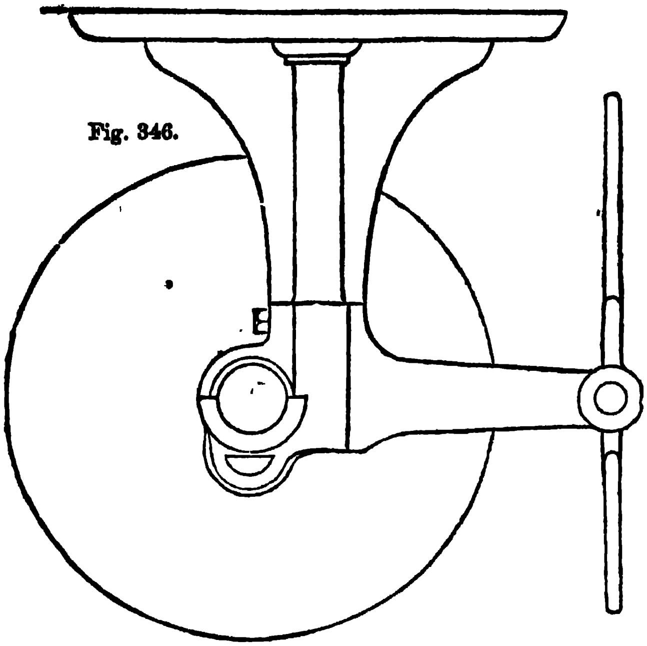


Fig. 346.

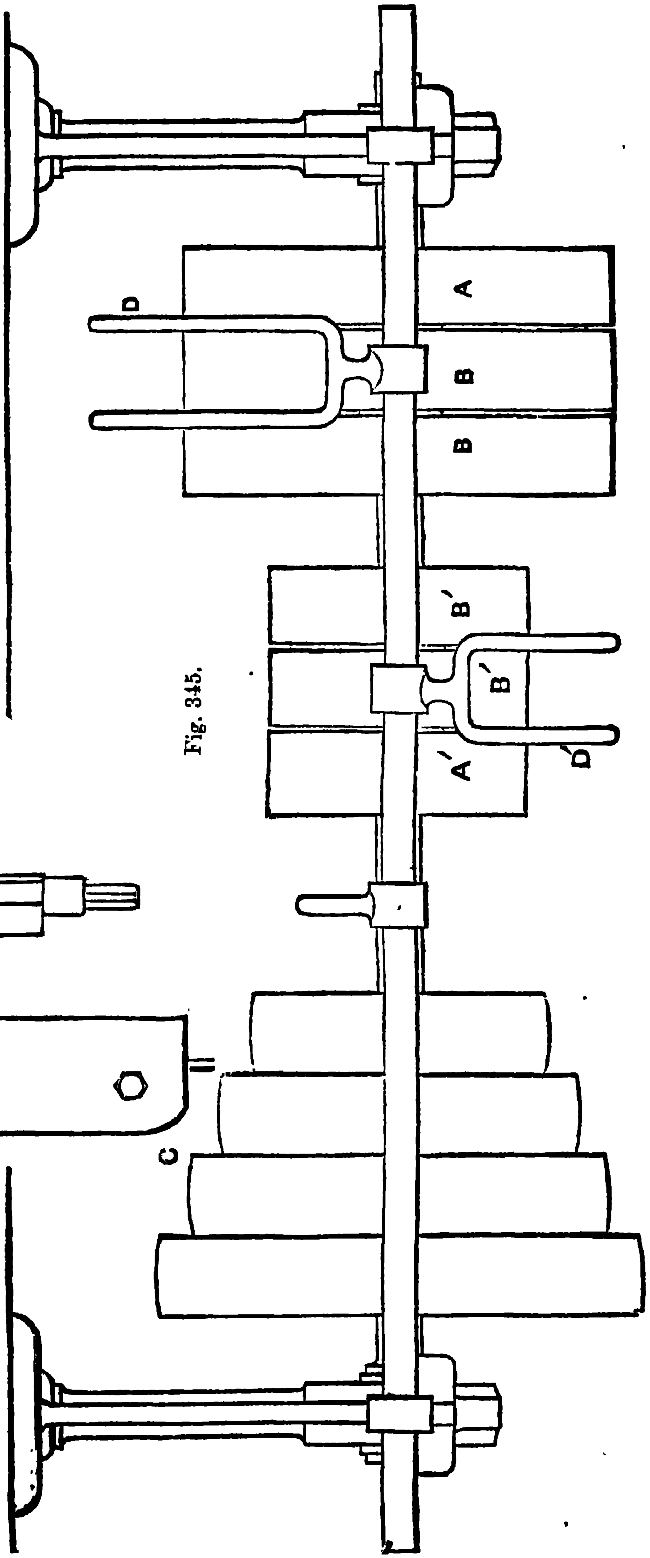


Fig. 345.

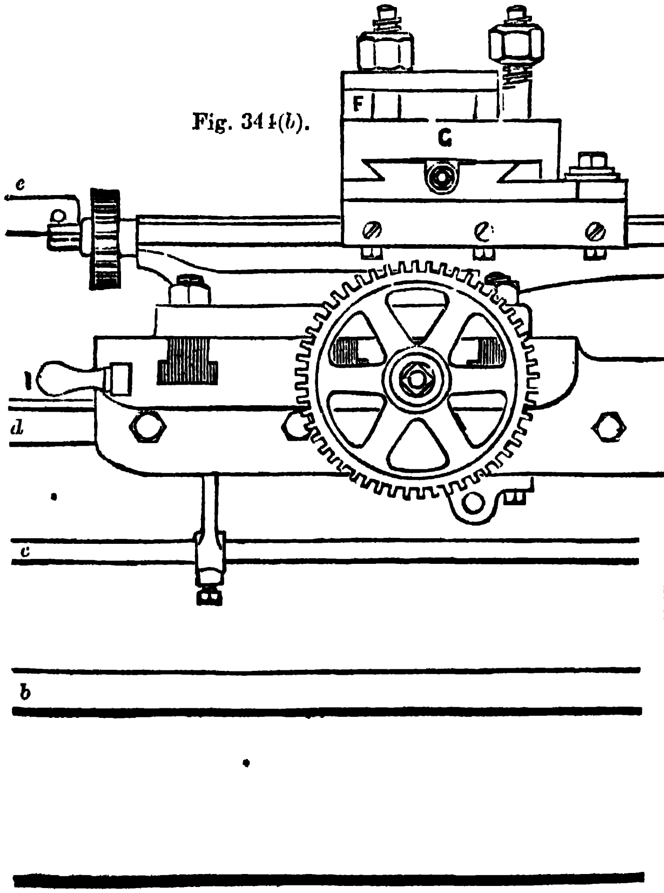


Fig. 344(b).

Figs. 345 and 346.—The countershaft which drives the lathe and receives motion from the main shafting.

Motion having been given to the cone-pulley A (Fig. 344 [a]), which runs loose on its shaft, is communicated to the large spur-wheel, B, by a key placed between them, and so the lathe-shaft is driven; or to produce a slower rate the key is removed, and the second motion, or back-gearing, brought into use, and driven by a pinion, C, attached to the hinder end of the cone-pulley. Another pinion on the second shaft, D (Fig. 348, which will also be given in the next lesson), drives the large wheel, B, so a double reduction of speed takes place. By the variation of speed due to the cones and back-gearing, eight different rates may be given to the lathe, and a suitable velocity imparted to any object held between its centres.

At the back end of the lathe are a set of change-wheels that give motion to the screw E, which runs along its whole length inside, and is protected by the bed. As their name implies, these wheels can be altered so as to give any desired speed to the travel of the tool F (Fig. 344 [*b*]), held in a slide-rest, G, and moved by the screw. By suitable proportions, threads of any pitch can be cut by the tool; and each lathe of the kind illustrated is provided with a complete set of toothed wheels, used either for sliding the rest slowly along, for turning shafting, etc., or cutting screws of any usual pitch.

The compound slide-rest, G, affords a means of placing the tool in any relative position to the work in hand: it consists of two V-slides at right angles to each other, which may be worked either by hand or self-acting arrangements, and a holder to carry the cutting tool. It is shown in front elevation at G (Fig. 344 [*b*]), and in side elevation at H (Fig. 348). The handle, I (Fig. 344 [*b*]), at the left-hand side, is for lowering or closing a nut upon the guide-screw, E (Fig. 344 [*a*]), so as to put it in or out of action, without reference to the change-wheels being in gear or not, and so give motion to the slide-rest.

A portion only of the bed is shown—its total length would be fifteen feet. The opposite end will be given in Fig. 347, which also illustrates the movable headstock. This contrivance is nothing more than a centre to carry one end of an object in a lathe, and capable of being fixed in any part of the bed by means of the two nuts shown. The wheel K (Fig. 347) works an internal screw that advances or draws back the centre point, L. A locking-bolt, M, of which the end only is seen, holds the centre whenever required.

The illustrations show a good example of a powerful slide and screw-cutting lathe; it is strong and well-proportioned in all its parts, yet not heavier than is required to resist the strain of working and the vibration to which it is subjected.

SANITARY ENGINEERING.—II.

GAS-BURNERS, AND ECONOMY IN GAS CONSUMPTION.

In our first paper we gave a general account of the manufacture of gas by public companies, the material employed, the processes to which it was subjected, and the method of its distribution. The gas being thus as it were brought to our door, or, to use the strictly technical phrase, "laid on," we now proceed to consider the various mechanical appliances used in its consumption: of these the simplest is the jet. A nipple of cast-iron or some incombustible material—porcelain has been used with advantage—is screwed on to the end of the pipe, the aperture through which the gas issues and is consumed being a small single perforation, which we may call a pinhole.

We next have what is in technical phrase called the "batswing" burner. In this, instead of the pinhole, the end of the nipple is first cast solid, and then split, as we may say, by a fine saw, the broad spread flame that issues from the opening thus made giving its name to the burner from its fancied resemblance to a bat's wing; these are, each of them, though the simplest forms in use, extravagant in their consumption, as the direct escape given to the gas allows a certain portion to pass through imperfectly consumed. They are still used extensively in passages, workshops, and other inferior positions; the idea in the mind of the public apparently being, that any cheap burner will do for these situations, while the actual fact is that the extra quantity of gas burnt in proportion to the price given for the burner, entails a current expense which would repay the cost of a better burner many times over in the course of a week. These burners also rapidly corrode the passage for the gas, which becomes gradually widened, and a still greater waste is the result.

The burner in most general use for ordinary purposes is the "fish-tail," as it is called, which may be taken as the best "burner" pure and simple, when no adventitious aid of chimneys or artificial draught is available. In this burner the gas comes up through two pinholes, inclined towards each other at an angle of about 60 degrees; the effect of the pressure being that the flame assumes a fish-tail, or, as it is called in some provincial districts, a tulip form, and is thrown out on either side at right angles to the converging delivery of the jets.

These are the leading forms of simple burners. With their combination in groups as cockspur, flower, and other lights, and more especially as to the employment of a group of fish-tails in the form of the sun-burner, we shall deal at length in a subsequent paper, and now proceed to take up the more complicated forms known generally under the name of "argand."

The term "Argand" is the name of the inventor, who in the year 1780 discovered in the use of an oil lamp that a circular wick open in the centre from below, and surrounded by a glass chimney, gave an immense additional per-centage of light over the ordinary methods then in use; and this principle is applied to the consumption of gas by the adoption of a hollow metal ring perforated on its upper surface with a number of minute holes through which the gas passes, the flames uniting into one annular light. The "bude light" is a concentric series of similar rings; and there are an immense variety of different descriptions of this kind of burner, many of them the subject of patents for various improvements of detail: *e.g.*, in some instances the burner is formed of a number of small tubes forming a ring, and with their points of issue slightly converging, while a bend in the glass chimney occurs immediately above, so as to direct the draught of air more immediately upon the flame; but the principle is always the same, the two important points which control the supply being the size of the openings in the burner, and the length of the chimney: this last is a point which requires much attention, as if the chimney be too low the draught is insufficient and the consumption too slow; while if it be too high the contrary effect takes place, and in either case loss of light is the result.

These are the ordinary descriptions of burner in general use; and we now proceed to consider the principles involved in the *economical* consumption of gas. It is well understood that the larger in bulk the amount of any substance in combustion the greater amount of heat and light are obtained, and this proportion may be termed geometrical and not arithmetical: for instance, a ton of coals burning in one body in a grate or furnace will generate a far greater body of heat (and light is regulated by the same law) than the same quantity divided, say, into portions of one cwt. each, and burned in twenty separate stoves.

We may give as a practical instance of this, as applied to the generation of light, our ordinary lighthouses. The old-fashioned catoptric light, as it was called, consisted of a group of argand burners, each with its separate reflector; when the dioptric system was introduced—where one large central burner only is employed—it was found that a large annual saving in oil was effected, the light given being equal in amount. The same principle applies to all gas-burners, with the addition of another element, and that is the variation of the pressure of gas, which exercises a most important influence, both on the light and the consumption of the gas. We state this as the result of actual experiment often repeated. Two fish-tail burners may be selected, one technically called a Number 3, a small size, and another a Number 6, a large size, the smaller size being supplied with gas at a high pressure, and the larger one with gas at a low pressure, the matter being so regulated, that in a given time, say an hour, each burner shall consume the same quantity of gas. The result has often been shown to be that the Number 6, the larger burner, at the lower pressure, gives *double* the light of the other, each burning the same quantity of gas; and the rule, therefore, is that the lower the pressure at which the gas can be burned the more light will be obtained in return for the quantity consumed. The most profitable point of a burner's consumption—profitable in the sense of economy—is that at which it is just at the point of (but not actually) smoking. The lower, therefore, the pressure at which the gas can be delivered to the burner, the more economically will it be burnt. And we derive also from this another general principle, of much importance in lighting all areas of any size, such as theatres, chapels, churches, warehouses, etc., and that is, that one large burner will give double, at least, the light of a number of small ones, even supposing the same quantity of gas is consumed in each case. The danger of having too large an area for the emission of gas from the burner is, that in case of an increase of pressure a certain waste ensues. This has been the subject of much attention to gas engineers, and has led, many years ago, to the invention of gas regulators, which, like the burners, have been the subject of various patents. The general principle upon which they are all constructed is to make the pressure of the gas itself the motive power which shall, by a self-acting process, control its own supply. This object is attained by an instrument constructed something on the principle of a miniature gasometer, through which the gas must pass when it leaves the meter and enters the service-pipes, the inverted tumbler or little bell of the regulator being provided with a valve which controls the exit of the gas by opening and closing. A high pressure lifts the bell, diminishes the opening of the valve, and reduces the supply of gas; a low pressure allows the bell to fall, thereby opening the valve and increasing it. They were made, when first invented, to be used with water; but as they have to be fixed within the house, and the water becomes rapidly impregnated with gas, an offensive smell was the result. This objection to their use, however, has been obviated of late years by the substitution of mercury (quicksilver) for the water, which keeps the regulator air-tight, and yet allows its freedom of movement. Where the pressure of gas is below the average, as in some low-lying districts, the regulator is not applicable; but in most cases, and certainly in all the higher parts of London, the force required to carry the gas through the long series of pipes is so great that their adoption affects a great saving. They are inexpensive machines, and have often been known to pay the cost of their introduction in the saving of gas effected in the course of a few months. Most of our readers have, no doubt, noticed the flaring that often comes on late at night, when the gas is being gradually turned off in the shops, which necessitates the "turning down" of the gas several times perhaps in the course of the evening; this is entirely controlled by the regulator, which secures a regular supply to the burners, and neutralises the extra pressure thus occasioned.

Further, we may remark that in many thousands of houses, by a careful re-consideration of the sizes and proportions of the burners required in the various rooms, and the introduction of a regulator, a saving of 30 per cent. of gas may be easily effected.

Our limits are nearly reached; but we will conclude with a few words on the removal of products of combustion where gas is largely employed—a point to which, from sanitary reasons, too much attention cannot be paid. This is sometimes effected, in the case of single burners, by a bell-glass, from the top of which passes a pipe into the nearest flue—a very desirable method where practicable. The late Professor Faraday invented a light in which an argand burner was entirely encased, chimney and all, in a large glass globe, from which was a pipe acting as a sort of flue; the effect being that the products of combustion were removed, either to a flue or the external air, without mingling in the slightest degree with the atmosphere of the room. And there are many similar adaptations of this principle, which has been introduced, among other places, at Marlborough House. Much the same effect is attained by the modern introduction of the "sun-burner," which also acts as an independent ventilator, removing the vitiated air from the upper portion of the room. It is, however, only applicable to comparatively large areas, and will probably form the subject of one of our subsequent papers; while the removal of gas products will be dealt with at length under the head of ventilation generally.

NOTABLE INVENTIONS AND INVENTORS.

XIII.—WILLIAM LEE AND THE STOCKING-FRAME.

BY JOHN TIMBS.

THE earliest stockings worn in England, by Henry VIII., were "cloth hose" or yard-wide taffeta, except there came from Spain, by great chance, a pair of silk stockings. Such is Howell's statement; but that woollen stockings were not only in use, but perhaps knit in this country, during the reign of Henry VIII., seems placed beyond doubt by this authentic household record: "1533, 25 H. 8. 7 Sept.—Peyd for 4 peyr of Knytt-hose, viiis." As early as the third year of Elizabeth we read that the queen's silkwoman presented to her majesty a pair of black silk knit stockings made in England, which pleased her so much, that she would never wear any cloth hose afterwards; not only on account of the delicacy of the article itself, but from a laudable desire to encourage this new English manufacture by her own example, and henceforth she wore no more cloth stockings. Soon after this (says Stow) William Rider, an apprentice at London Bridge foot, opposite the church of St. Magnus, seeing a pair of knit worsted stockings at an Italian merchant's, brought from Mantua, borrowed them, and having made a pair like them, presented them to the Earl of Pembroke, which was the first pair of worsted stockings knit in this country.

The manufacture of stockings by the humble process of knitting is, in strictness, to be called "chain weaving;" for the fabric itself is actually produced by a series of links or loops in a thread of worsted, cotton, or silk. In the process of knitting, still carried on to a small extent in secluded country districts, polished steel needles or wires are used to link the threads together into a series of loops, closely resembling in their character the loops produced by tambouring. But this method was almost entirely superseded by the ingenious stocking-frame, which, next to the common warp and weft loom, is the oldest machine in existence applicable to textile fabrics. It dates from almost immediately after the introduction of knit stockings, or from 1589, the thirty-first year of Elizabeth's reign.

In the early history of the stocking-frame there is a strange confusion of persons, places, and dates, in the accounts given of the invention and the inventor, which neither Beckmann nor any other inquirers have entirely succeeded in removing, unless we implicitly believe the evidence of a painting which long hung in Stocking Weavers' Hall, Redcross Street, Cripplegate, long since taken down. This picture contained the portrait of a man in collegiate costume, in the act of pointing to an iron stocking-frame, and addressing a woman who was knitting with needles by hand. The painting bore the following inscription: "In the year 1589, the ingenious William Lee, A.M., of St. John's College, Cambridge, devised this profitable art for stockings (but being despised, went to France), yet of iron to himself, but to us and to others of gold: in memory of whom this is here painted." From Deering's "Account of Nottingham," it appears that William Lee (whose name is sometimes written Lea) was born at Woodborough, a village about seven miles from Nottingham: he is said to have been heir to a good estate, and he was a graduate of St. John's College, Cambridge. Tradition assigns the origin of Lee's invention to a pique he had taken against a townswoman with whom he was in love, and who, it seems, slighted his passion. She got her livelihood by knitting stockings, and with the ungenerous object of depreciating her employment he constructed this frame, first working at it himself, then teaching his brother and other relations. Another account states that the girl, during his visits, paid more attention to her work than to her lover, and he endeavoured to find out a machine which might facilitate and forward the operation of knitting, and by this means afford more leisure to the object of his affections to converse with him. Beckmann, however, argues that a machine so complex in its parts as the stocking-frame, and so wonderful in its effects, would seem to require longer and greater reflection, more judgment, and more time and patience than could be expected in a lover.

Another version of the story states that Lee was expelled the University for marrying contrary to the statutes. Having no fortune, the wife was obliged to contribute to their joint support by knitting, and Lee, while watching the motion of his wife's fingers, conceived how to imitate those movements by a machine. Both accounts agree that the stocking-frame was invented by Lee. A writer in the *Quarterly Review*, however, observes: "This painting might give rise to the story of Lee's having invented the machine to facilitate the labour of knitting, in consequence of falling in love with a young country girl, who, during his visits, was more attentive to her knitting than his proposals; or the story may, perhaps, have suggested the picture."

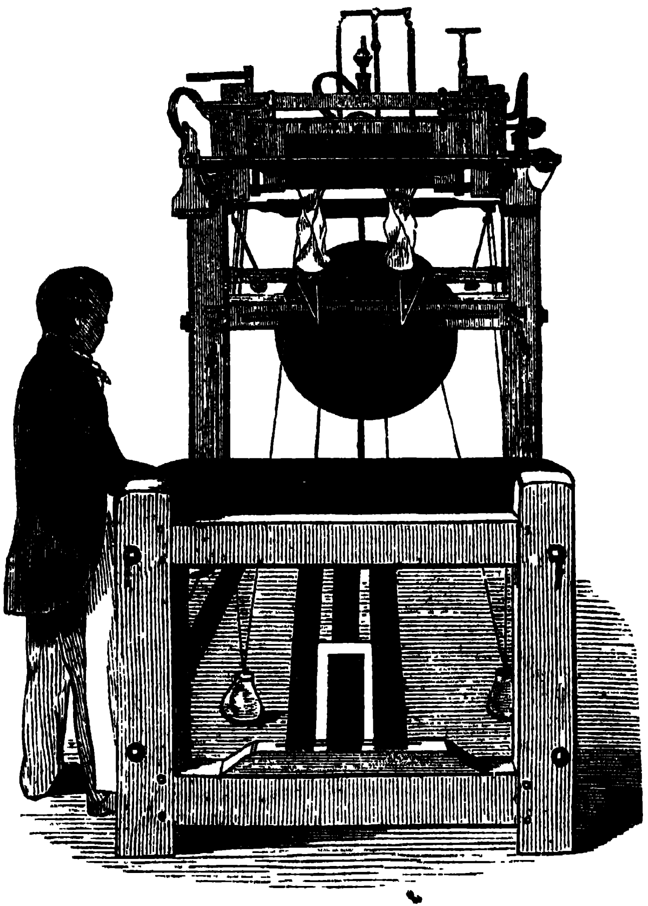
There is, however, another claimant. Aaron Hill ascribes the invention to a young Oxonian, who having married imprudently, and having nothing to support his wife but the produce of her knitting, invented the stocking-frame, and thereby accu-

mulated a large fortune; but Hill wrote this story in 1715, upon hearsay. Evelyn, in his "Diary," records having seen this machine as follows: "3 May, 1661. -I went to see the wonderful machine for weaving silk stockings, said to have been the invention of an Oxford scholar about forty years since;" thus placing the invention many years later than the date of the picture in Stocking-Weavers' Hall. Evelyn's version is not a whit more exact than Hill's, which Elmore has followed in his very clever picture, painted in 1847.

Lee practised his new invention some time at Calverston, a village about five miles from Nottingham, and he, or his brother, is said to have worked for Queen Elizabeth. Another account states that Lee, finding himself neglected both by the queen and her successor, James I., and much annoyed by other stocking manufacturers bringing his invention into disrepute, transferred himself and his machines to France, where Henri IV., and his sagacious minister Sully, gave the inventor a welcome reception. Lee is said to have carried over nine journeymen and several looms to Rouen, in Normandy. Nevertheless, after the assassination of Henri, Lee shared in the persecutions suffered by the Protestants, and is said to have died in great distress, of grief and disappointment, in Paris. Seven of Lee's workmen escaped to England, and with Lee's apprentice, one Aston, established the stocking manufacture permanently in England. Aston, who had been a miller, added something to his master's invention. Stow says that Lee not only manufactured stockings in his frame, but "waistcoats and divers other things."

In the year 1663, Charles II. granted to the Framework Knitters' (stocking-makers') Society of London a charter, which Cromwell had refused to them a few years before. In their petition, the machine is described as consisting of 2,000 parts, and making almost instantaneously 200 meshes. Six years afterwards, the number of stocking-frames in England amounted to 700, employing 1,200 workmen, of whom three-fifths made silk stockings, and the others worsted; for cotton was not then ranked among English manufactures. By the year 1714 the number of frames had increased to 8,000 or 9,000. Our makers soon exported vast quantities of silk stockings to Italy, where they recommended as "right English." By the year 1753, about twenty years after the introduction of cotton stockings, the number of frames in England was 14,000. Mr. Jedediah Strutt, of Belper, invented in the year 1758 a machine for making ribbed stockings, which he patented; the patent was twice contested, first by the houses of Derby, and then by those of Nottingham; but the validity of the patent being established, the inventor enjoyed it for fourteen years. The rib stocking-frame was one of the contrivances which led by gradual improvements to the net machines.

Here it may be interesting to trace the picture of Lee and his wife, which appears to have been parted with by the Framework Knitters' Company at a period of pecuniary embarrassment. Mr. Bennet Woodcroft has collected some particulars of the disposal of the picture, in the hope that they may lead to its recovery. In a list, dated 1687, of plate, paintings, etc., belonging to the Company, is this item, "Mr. Lee's picture by Balderston." It is described also in Hatton's "London," 1708. *From 1732, the Company's books show no more meetings at the hall, or any further entry of the picture. The stocking-weavers subsequently let their hall, and met at various taverns.* The head of the court summons, dated 1777, is engraved from Lee's picture, and from this plate is copied an engraving in the Gallery of the Portraits of Inventors in the Great Seal Patent Office. The picture is thought to have passed, about 1773, into the hands of an influential member of the Court of Framework Knitters, who from time to time lent the Company money, as their books testify. ("Curiosities of London," 2nd edit.)



THE STOCKING-FRAME.

The common stocking-frame is a quadrangular arrangement of upright posts, connected by cross pieces at the top, and having on one side the weaver's seat. Near this is placed a series of curved needles, which serve as knitting needles in forming the loops, in number according to the coarseness or fineness of the stocking. The stocking-frame has a series of vibrating levers, called jacks, which, aided by other intricate apparatus, throw the stocking-yarn into such curvatures as enable the needles to form the loops. The weaver has a bobbin-yarn at one side of his frame, from which he unwinds enough to lay across all the wires. He then, by moving certain treadles with his feet and levers with his hands, forms this length of yarn into a row of loops; and at the next movement, when forming another row of bends or loops, he links the one row into the other, so as to form a kind of chain, which chain, extending both lengthwise and across, constitutes the web of the stocking. One continuous thread forms both warp and weft; and as the thread is not by this operation tied into knots, such as occur in making nets, the meshes are loose; but at the same time the web acquires a degree of elasticity which no other form of woven plexus presents.

There are three classes of operatives engaged in the manufacture: the *winders*, who put the silk, cotton, or thread on the bobbins; the *stockingers*, or *framework-knitters*, who work the thread into a knitted fabric; and the *seamers*, who make the stockings out of the pieces thus produced. Some of the frames are owned by the workmen, and some are lent out or rented. Stocking-frames with a rotatory motion, and worked by steam-power, have superseded the old unpromising engine, and effected very great economy. The working of a rotatory machine, impelled by steam, in which the new-fashioned stockings are made at the same time, will require the superintendence of only one man and a boy; whereas, in the old frame, but one stocking could be made at once by a single workman.

Loughborough is a chief seat of some manufactures of the best hosiery. The stockings known as Angola and Merino are made on the principle of combining worsted with cotton in nearly equal proportions; and the peculiar features of the best make are the close and intimate intermixture of the fibres of the wool and cotton. The separate materials are first passed through a machine called a picker and blower, the object of which is to clean and lighten it, so that half an ounce would fill a bushel measure. They are then carded together by carding machines, part of each material being dyed blue or black, and the intermixture is effected by the carding. It is next spun of various fineness by throstles and mules, and then given out to be woven.

FORTIFICATION.—VI.

BY AN OFFICER OF THE ROYAL ENGINEERS.

FLANK DEFENCE FOR REDOUBTS.

THE obstacle offered by the ditch of a work, with the dimensions usually attainable in the field, is so inconsiderable that it is of the greatest importance to provide some flanking defences for it, to increase the danger and difficulty of an assault.

The arrangements for attaining this end, by means of fire from the parapets, enable the defenders to take the storming parties in flank while crossing the glacis, as well as when actually in the ditch itself; but, on the other hand, it seems doubtful whether this advantage is not more than counterbalanced by the attendant defects of increased length of parapet and liability to enfilade, which would probably cause the flank defence to be crippled at the very instant it was most required, viz., the last moments of the attack.

To these reasons, and also to the fact that the simple trace of a redoubt is more capable of adaptation to irregular ground than that of a fort, is probably owing the circumstance that in almost every instance when closed field-works have been employed of late years the former trace has been adopted—*e.g.*, the Danish redoubts at Düppel, 1864; the double line of redoubts round Vienna, 1866; and the works thrown up round Dresden by the Prussians in the same year. In all these cases the works were traced rather with reference to the directions in which offensive fire was required, and to the reciprocal flanking fire of the collateral works, than to any idea of their own flank defence; and in many cases the ditches were altogether undefended.

That such flank defences, however, are still thought advisable by foreign as well as English engineers may be seen from the fact that in the works of this class at the Russian intrenched camp in Finland the ditches are defended by kaponiers, and that they have been provided for in the approved type of hasty redoubt in the latest work on military engineering at Chatham.

Flank defence for the ditches of redoubts is obtained by building covered loopholed galleries in them in such positions that, while being well screened from the enemy's distant fire, they thoroughly command one if not two ditches (Figs. 41, 42). These are called kaponiers and reverse or counterscarp galleries, according to their position. Their actual construction is simple enough, and yet from the fact that they are necessarily at the bottom of the ditch, and that their roofs are covered with earth, it follows that they cannot be begun until the ditches are nearly finished, and that some of the earth will have to be moved twice; consequently, when the works are hastily thrown up it will often be impossible to get these buildings constructed, however desirable and even necessary it may be to do so.

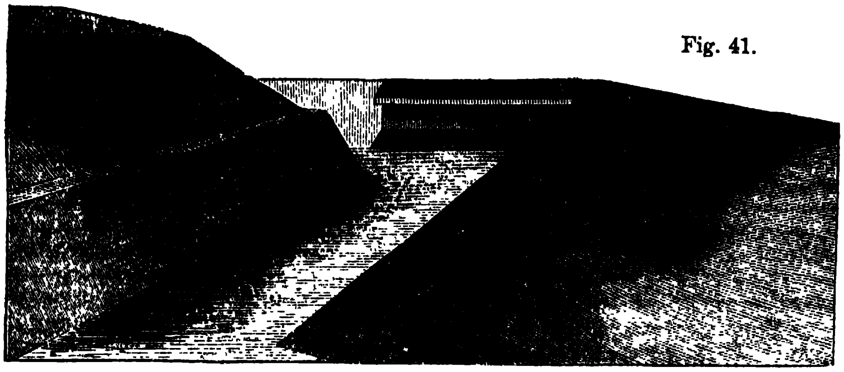


Fig. 41.

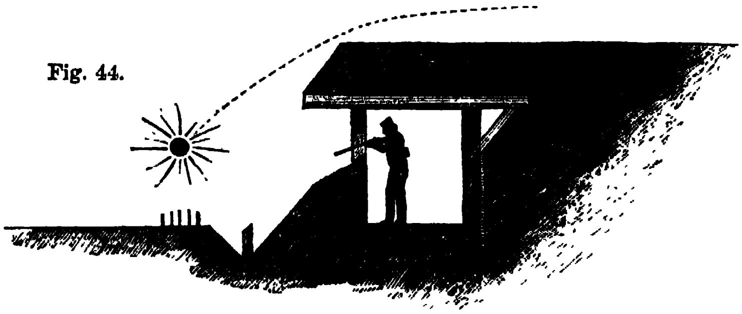


Fig. 44.

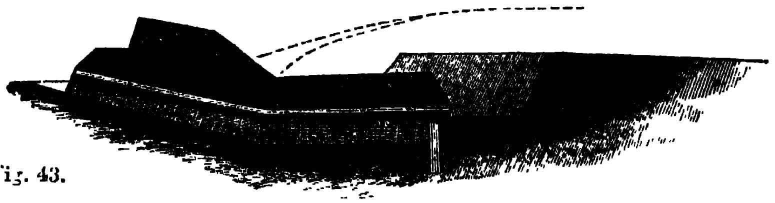


Fig. 43.

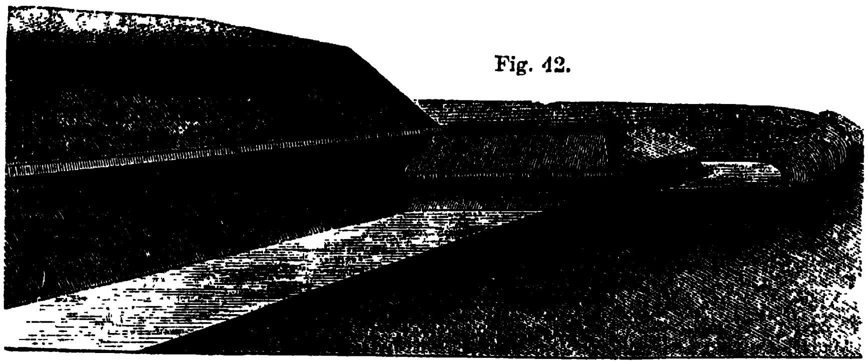


Fig. 42.

In some cases, when the skilled labour of sappers is available, time may be saved by laying the roofing beams on the ground in the ditch at the required level, and then employing a double set of workmen, one excavating the earth under the beams to form the interior of the gallery, while the other excavates the ditch, and forms the roof with the earth thrown out.

In this case of course the sides of the gallery are of earth, but as a rule the side and front walls are constructed of stoccade work, roofed in with thick beams of wood, covered by a sufficient thickness of earth, usually from three to five feet (Figs. 42 and 44).

A kaponier is a loopholed building projecting from the escarp across the ditch; and, in order to obtain as much fire as possible from it, the length of its sides should be the full width of the ditch; but as the roof would then afford a ready means of entering the work, the ditches at these points are carried round the end of the kaponier to prevent this. There is usually a covered passage leading from the interior of the work to the kaponier, to enable its garrison to be reinforced, and which enables them to retire to assist the defence elsewhere when no longer required at their post.

Kaponiers in permanent works are large casemated masonry buildings, mounting one or two tiers of guns; but in field-works they are only constructed of timber, and consequently are liable to be destroyed by the enemy's pitching fire, unless the roof is sunk well below the crest of the glacis. To do this, and at the same time retain sufficient thickness of roof and head-room for the defenders inside, it is in many cases necessary to sink the floor below the level of the bottom of the ditch. This brings the loopholes close to the ground, and exposes as little as possible of the stoccade timbers, but has the disadvantage of being liable to be flooded in wet weather; and, moreover, the loopholes, if very low down, may be masked and rendered useless by the earth dislodged from the escarp by the explosion of the enemy's shells forming mounds in the ditch.

Reverse or counterscarp galleries are similar in construction to kaponiers, but are placed under the glacis, their front wall being the counterscarp of the ditch (Fig. 43). They have the advantage of being more secure from the enemy's fire, but have no means of communicating or receiving assistance during the fight, and the retreat of their defenders would inevitably be cut off should the enemy gain possession of the works.

It must be understood that in permanent works where this method of flank defence is adopted, this latter defect does not exist, as a passage is usually constructed under the ditch communicating with the interior of the inner work.

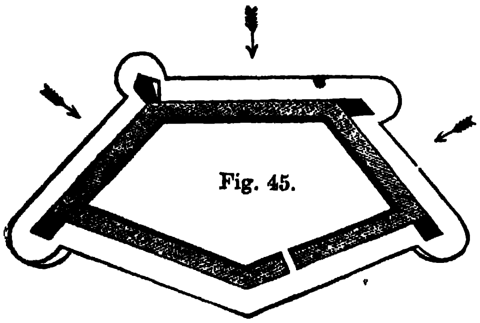


Fig. 45.

In redoubts whose ditches are twelve or thirteen feet below the crest of the glacis, it is not necessary to sink the floor of the counterscarp gallery below the level of the ditch, as that height is sufficient to admit of seven feet head-way inside, as well as a thickness of roof of five feet (Fig. 44). To protect the timbers of the front of the gallery from the splinters of shells bursting near them in the ditch, a small excavation should be made at the bottom of the ditch, and the earth from it piled against them as high as the bottom of the loopholes (Fig. 44). This excavation, if provided with pointed stakes, will assist the defence, by preventing the enemy from closing with the loopholes from outside.

The position of these defences with reference to the direction of the enemy's fire is very important, and can only be determined by the special conditions of each case. Field-works, even when closed, and therefore capable of resistance in any direction, are really always part of some general line of defence against an enemy advancing in certain known directions; the sides, therefore, most liable to attack can generally be determined on when the plans for the work are drawn up, and the kaponiers or galleries placed accordingly. The accompanying diagrams (Figs. 45 and 46) show the way in which either of these types of defence may be applied to flank the ditches of an ordinary pentagonal redoubt; but it is by no means necessary that the whole of the ditches need be flanked in the same manner, a combination of the two being frequently advisable.

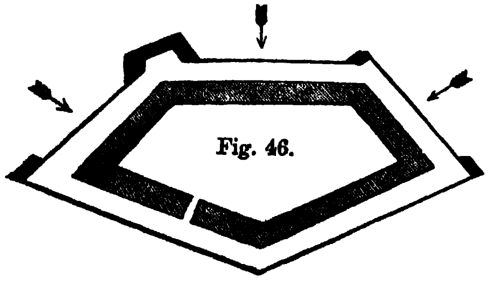


Fig. 46.

The defence of a field-work may be rendered more obstinate by the construction of a small central work within it, which is capable of being defended after the main work has fallen. Such a work is called a *reduit*, and may be either a small earthen redoubt or a loopholed building, with a bomb-proof roof similar in construction to a kaponier. In the former case the parapet of the reduit should be somewhat higher than the outer work, to prevent the enemy from seeing into it when standing on the parapet of the main work; but in the latter the block-house (as such a reduit is called) should be as low as possible, to protect the walls from fire, while its loopholes command the whole interior of the main work. Reduits are useful in affording protection to the stores and reserves of the garrison, and either contain or (if block-houses) are themselves the barracks for the troops. Reduits of permanent forts are large casemated buildings, placed near the gorge of the works, and containing the principal magazines. They also communicate directly with the kaponiers and galleries of the outer work, and have generally ditches and flank defence of their own.

FARMING AND FARMING ECONOMY.—I.

By Professor Wrightson, Royal Agricultural College, Cirencester.

Rural economy has from the earliest times been divided into agriculture proper (*agricultura*) and the management of stock (*pastio*); the first having reference to the cultivation of the ground for crops, and the second to the pastoral occupations of breeding and rearing cattle. In treating of farming and farming economy, however, we shall find that on the greater number of farms these two branches are united, giving rise to what is conveniently named "mixed husbandry." Under the common name of "agriculture" the management of both "stock" and "crop" is usually included, and both classes of produce will occupy our attention in the following series. The importance of this art is most thoroughly seen when we reflect upon its universality, the many forms in which it meets us throughout the world, and its direct and indirect effects upon the well-being of the human race. The culture of plants and domestication of animals render the necessaries of life abundant, and a large population possible. The more, indeed, we reflect upon agriculture, the clearer do we see its vast importance. We recognise in it the underlying tissue binding the members of a nation into one; the source of food, of clothing, and of luxuries; and an employment for the greater part of the human race. It is with such a subject we have now to deal, and at the outset it would be well to settle how we may best consider it. In the first place, we must restrict ourselves to English, or at most to British farming, and that principally of our own time. Such attention we must give to the history of the art as will be necessary to make our own customs and notions intelligible; and in bestowing it we shall see that while generation after generation have profited by a long experience, they have also handed down to us obsolete ideas which to this day shackle us.

The history of agriculture appears to have been affected by three distinct but parallel influences. First, the law of landed property, rendering the owning and holding of land possible, conferring power upon the owner, and greater or less security upon his dependants. Secondly, the accumulated experience of the art, aided from without by other branches of knowledge. Lastly, we have the influence of the growth around agriculture of numerous industries formerly unknown, in turn checking or encroaching upon it, or stimulating it by home and foreign competition of various kinds to fresh exertions. We shall glance briefly at the first two classes of causes; but the last extends over too wide and varied a field for present consideration.

The most casual observer of the economical condition of land as a property in this country will note that for the most part it exists as large estates owned by our aristocracy and gentry, and farmed by tenants removable at the will of the owner, or, more strictly, superior tenant, commonly called owner. Lastly, there is the labourer, on whom ultimately falls the burden of actually cultivating the land and securing its produce. The "owner" is entitled to rent, "which implies a return in service, corn, cattle, and money from the land demised" (Bayldon). He also retains the right of re-entry, after legal notice, and certain rights as to woods, mines, game, etc., which need not now detain us. The tenant, usually termed the "farmer," is, under certain restrictions or limitations, allowed to apply his capital in cultivating the land, and is entitled to the surplus profits, after rent and other burdens have been paid. He has, however, too frequently no permanent interest in the land, and is liable to eviction at six months' notice from the landlord or his agent. The labourer has no legal interest in the land, but is entirely dependent upon the farmer, for whom he works at weekly or daily wages.

To this threefold system of landlord, tenant, and labourer, the term "farming" properly belongs. This word is now for the most part used to denote the occupation of agriculture, and the estate or land itself is usually spoken of as a "farm." The occupations of agriculture and farming are, however, by no means synonymous terms, since farming presupposes the payment of rent, and involves tenancy. "Farm, or *feorme*," writes Bayldon, in his "Rents and Tillages," "is an old Saxon word, signifying 'provisions,' because anciently the rents were paid in produce, and were altered by the introduction of money. A farmer, or *firmarius*, was one who held his lands upon paying a rent, or *feorme*." When a landlord cultivates his own property he is not strictly speaking a farmer, although in ordinary language he may be so designated; and, again, by the payment of a fixed rent or share in the profits, the farming system has been introduced into mining, tax-collecting, and other occupations altogether unconnected with the cultivation of the soil. The agriculture of this country is for the most part carried on by a system of farming or hiring—a system springing naturally from the great extent of landed estates which could not well be cultivated by their owners, and are therefore let to tenants. How far the system of tenant-farming is the best for the land and the community is a question upon which much may be said; but we may safely conclude that it is the only system compatible with the large estates into which England is divided, and that it has many solid advantages. To the landlord it gives an assured revenue, and to the tenant it offers a fair profit upon capital invested. The labourer is, however, less fortunate, and there is reason for thinking that the system of letting land places him in an unsatisfactory position; the tenant scarcely having a sufficiently permanent interest in the land to warrant him in expending capital on labourers, while the landlord, so long as his rent is paid, has no direct or pressing reason for attending to his requirements.

Familiar as our system of landowning and hiring is, it had a commencement and rise which may be traced with the aid of history. In the fourteenth century traces are met with of an older system of landed property, which at that time had well nigh disappeared. We refer to the old Teutonic "mark," or "township," with its three constituent parts—"the 'common mark' (the *folc-land* of the Anglo-Saxons), owned jointly by the community; secondly, the 'arable mark' (*feldmark*), cut out of the common mark, and apportioned in equal lots to the members of the community (the Anglo-Saxon *boc-land*); and, lastly, the 'mark of the township' (*dorf*, *thorp*, *villa*), also divided into individual lots, and individually appropriated."*

This primitive distribution of land had at the period specified ceased, and the lord of the manor had obtained an overlordship or suzerainty over those who had formerly been his equals. Thus, according to Professor Rogers, in the thirteenth and fourteenth centuries "the parish or manor was divided into four portions. First, the lord held, together with his feudal rights over the whole, except the glebe of the parson or impropriator, a demesne, which he cultivated by his bailiff; secondly, there were the small estates possessed by the freeholders, who paid quit-rents; thirdly, there were the tenements and lands of *villains*, *bordarii*, or *cotarii*; and, lastly, the waste or common, over which all tenants had right of pasture, and sometimes of turf." The freeholder was, in fact, a farmer at a perpetual lease, and is the predecessor of the freeholders of the present day, who still pay quit-rents to the lord of the manor. Next, and below the free tenants in rank, are the *nativi*, or *villains*, and the *coterelli*, or *cotarii*, holding their tenancies at agricultural services, these services being commutable for specified sums of money. The position of the *villain* was servile, and in many respects unfortunate. They are the forerunners, not of tenant-farmers, but of copyholders, and could not readily be evicted by their lords at the time before us.

Previous to this time, as already stated, the lord's demesne had been cultivated by means of a bailiff, a custom generally discontinued after the Plague, which first devastated the country in 1348. Professor Rogers states that Merton College, Oxford, let their estate at Ibstone, in 1300, for thirty-five years, and that after the Plague most of the college estates were let; also, that about the year 1381 the leasing of land became general. At this time the freeholder held an independent and safe position, and even the copyholder, or tenant in villenage, was a permanent tenant, whose land could not be entered by the lord. We may therefore fairly date the custom of letting land, and the rise of the important body of tenant-farmers, from the commencement and middle of the fourteenth century.

The mass of peasant proprietors, comprising *socage* and *villain*, or free and copyhold tenants, has been steadily absorbed by the purchase of their lands by the great landowners, so that at the present day they have, as a class, almost disappeared; and in the place of the lord of the demesne cultivating his own estate through his bailiff, and surrounded by a more or less free tenantry, we have the modern economy of landlord, tenant, and labourer.

In contrasting modern farming with the cultivation of the thirteenth and fourteenth centuries, we become conscious of the immense improvement which has gradually taken place. At that early date wheat, barley, oats, rye, beans, peas, vetches, etc., were all in ordinary cultivation, and the usual domestic animals were present as live stock. There is also an unexpected uniformity of management or practice in estates far remote from each other, which suggests a freer means of communication between various parts of the country than might have been supposed to exist. Root-crops were, however, unknown, and winter feeding of stock was therefore impossible. The so-called "artificial" grasses and clovers (seeds) had not yet appeared; implements were rude, and manure was sparingly employed. The imperfect method of cultivation is best shown by the small return in proportion to the seed sown. The amount of seed approximated to that now used by many farmers—namely, two bushels of wheat, rye, beans, peas, and vetches, and about four bushels of barley, bere, and oats. The records of Merton College, Oxford, which have been so ably edited by Professor Rogers, supply exact information as to the yield of grain upon various estates during the season 1333-4. "Wheat at Maldon returns about four times the seed; at Leatherhead, less than three; at Farley, less than four; at Cambridge, about four; at Wolford, more than eight times; at Cuxham, about four and a half times; at Holywell, nearly eight times; at Basingstoke, about three times the quantity sown." An average crop of wheat at the present day has been variously estimated, but twenty-eight bushels per acre is probably very nearly correct over the whole of England, while thirty bushels is commonly looked upon as a fair crop. We see, then, that modern culture has greatly increased the amount of produce per acre in the case of wheat, and the same is true with regard to other crops.

In tracing the history of the various improvements introduced into British agriculture we shall do little more than indicate the period at which they occurred. "Great clover," and probably turnips, were introduced by Sir Richard Weston, about 1645. In the third edition of Blythe's "Improver Improved" (1662), both clover and turnips are noticed, and a considerable share of attention is bestowed upon drainage and other improvements. In Haughton's "Collections on Husbandry and Trade," a periodical commenced in 1681, occurs the first notice of sheep being fed upon turnips upon the land. It was about this time that the potato began to attract the attention of agriculturists, although previously known as a garden vegetable. At the beginning of the eighteenth century, clover and rye-grass appear to have been sown together, and cut as green food; and at this period Jethro Tull perfected his system of drill husbandry and horse-hoeing. Turnip husbandry also appears to have greatly extended in the middle and towards the close of the last century, thus preparing the way for the maintenance of the improved races of domestic animals now about to appear. About the year 1755, Robert Bakewell, of Loughborough, Leicestershire, turned his attention to sheep and cattle breeding, and introduced the famous Leicester or Dishley sheep, and the "longhorn" race of cattle. Subsequently Charles Colling (formerly a pupil of Bakewell) and his brother Robert brought out the celebrated short-horn race, by improving the native cattle of North Yorkshire and South Durham (the Teeswater breed) by careful selection. The present century has been remarkable in the progress of agriculture. It is during this period that agricultural societies have been founded, and have arisen to their present importance; that agricultural colleges have been opened, that steam has been applied to cultivation and thrashing, that chemistry has revealed the true nature of foods and fertilisers, and that a steady improvement has taken place in live stock and cultivated plants.

For fuller information on the above interesting points relating to ancient agricultural customs the reader is referred to Professor Rogers' "History of Agriculture and Prices" (Clarendon Press, Oxford), and Maine's "Village Communities in the East and West" (John Murray).

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* Morier, "System of Land Tenure in Various Countries: Germany."

OBJECT DRAWING.—III.

Fig. 11 represents a cube placed on the left side of the spectator; and on this cube rests a square pyramid.

Having already given the elementary principles on which the view of the cube is based, it is only necessary here to refer to the pyramid which is drawn separately in Fig. 12.

Let A B be the side of the base of the object. From A and B draw lines to the point of sight; and it will be clear that portions of these lines will be the sides of the square, which, being at right angles to the plane of the picture, converge to the point of sight.

The line C D will give the back line of the figure, which thus represents the "plan" of the pyramid, or the piece of ground on which it stands.

The exact position of the apex or point is next to be considered. Now, although in the mere elevation (that is, the view in which only the front of the object would be shown) the apex would be immediately over E, the middle of the base of the isosceles triangle, this is not the case when the eye is moved towards either side of the object; for it must be remembered that the apex is *not* over the middle of the *side*, but over the middle of the *square* forming the *base*.

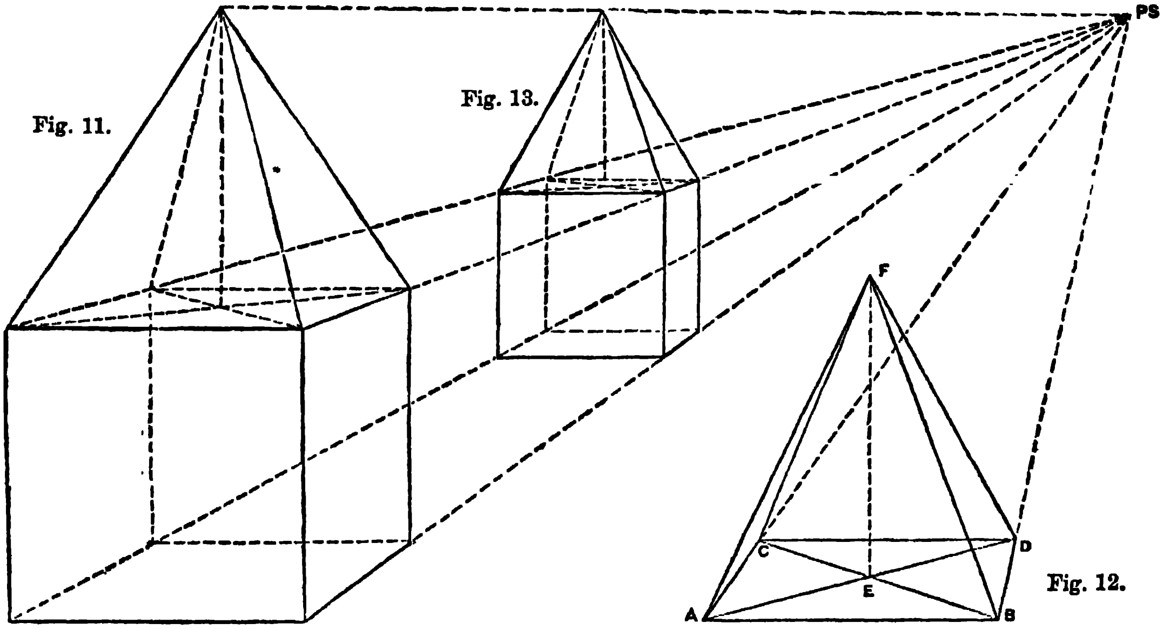


Fig. 11.

Fig. 13.

Fig. 12.

Therefore, having sketched the figure A C D B, draw diagonals the intersection of which, E, will clearly give the centre of the base. On this point erect a perpendicular; mark on it the apparent height F, and draw F A, F B, F D; the line F C may be lightly drawn, which will give a transparent appearance to the drawing.

Having thus studied both the objects of which Fig. 11 is composed, it will be a comparatively easy task to draw the two when combined.

Draw the cube as already shown, and as the base of the pyramid in the present case corresponds in size with the sides of the cube, draw diagonals in the upper surface, and, as in Fig. 12, erect a perpendicular on which the apparent height is to be marked; the object (Fig. 11) is then to be completed as before.

The student is advised in most cases to sketch the objects as if transparent. These interior lines may, of course, be rubbed out before shading; but they will be a great guide in testing the correctness of the general form, and will materially assist in finding the distant points of the figure and the position of the objects in relation to each other.

Fig. 13 is the same view, representing the object when removed from the immediate foreground. In this view the object is supposed to have moved backward in a direct line from Fig. 11, as if guided by a tramway; the student will thus be able to account for the diminution in size.

It must be pointed out, that the apex of the pyramid in Fig. 11 is only over the intersection of the diagonals of the cube, because the pyramid is placed so that the edges of its base correspond exactly with the edges of the top of the cube. Other circumstances will be considered in future lessons.

Fig. 14 is a cube on which rests a pyramid, the apex of which is not over the centre of the top of the cube. Having sketched the cube as in former lessons, draw the line A B representing the front edge of the base of the pyramid.

As the pyramid is to be represented as if moved forward, this line must of course be drawn in front of C D, the edge of the cube, and although it would in reality be the same length, it must be longer than C D, being, in fact, the most prominent line in the picture. You will understand this if you refer to the cut in Lesson I, in which D E represents the line on which the picture-plane stands.

Now, if you place such a plane in front of the present subject, and gradually move it nearer and nearer to it, the first part at which it would touch would be the line A B.

From A and B draw lines to the point of sight; for although the pyramid has been moved sideways and forward, its edges have been kept parallel to those of the cube, and the lines A E and B F in the model are at right angles to the plane of the picture. Next draw the line E F, which completes the base of the pyramid. In the quadrilateral A B F E draw diagonals; at their intersection erect a perpendicular equal to the apparent height, G, of the object; and finally draw G A, G B, G E, and G F.

Fig. 15.—This is a cube resting on one of its edges, whilst another touches the cube, Fig. 14.

Now it is necessary to bear in mind, that although this cube rests on one edge only, the plane of the side A′ B′ C′ D′ is parallel to the picture. To prove that this is so, place the cube, in the first instance, on one of its sides, the face A′ *b c d* being parallel to the picture, as in Fig. 14; raise the object at *b*, until the edge *d* rests against the side of the cube (Fig. 15 at D′). It will then be evident that the object has merely rotated on A from left to right, but that the surface remains parallel to the picture-plane as before.

The shape of the front therefore remains unaltered—a perfect square—but resting on the angle A′ instead of on the side A′ *b*.

To draw this object, draw the line A′ D′, carefully observing (1) that it must be of the length of the side of the cube (Fig. 15), the cubes being equal, and (2) that it slants in the degree required; the line A′ D′ forms the hypothenuse of the right-angled triangle A′ E D′, and by comparing the angles at A′ and *b*′ in your drawing with those formed by the meeting of the two models, you will soon discover whether the cube is sufficiently inclined.

On A′ D′ draw the square A′ B′ C′ D′, which will give the face of the cube in the position required.

Reverting to the original cube drawn in dots, it will be seen that the edges *b b′* and *c c′*, being at right angles to the picture, converge to the point of sight, and this will still be the case, for though the edges of the cube have altered in *position*, they have not altered in *direction*, but still run directly from the foreground into the distance at right angles to the plane of the picture. Therefore from A′, B′, C′, D′ draw lines to the point of sight.

The line drawn from D′ will cut the distant perpendicular of Fig. 14 in E′, and as the cubes are equal, this will determine the depth of the distant sides; therefore from E′ draw a line parallel to D′ A′, cutting a line drawn from A′ to the point of sight in F. Also from E′ draw a line parallel to D′ C′, cutting a line drawn from C to the point of sight in H. From F draw a line parallel to A′ B′, cutting a line drawn from B′ to the point of sight in G. Draw G H, which will complete the object.

Fig. 16.—This figure is composed of four equal blocks, or solid oblongs; they are equal in length, and since they are not mitred at the angles, the figure they form is not a square. To make this clear, let us suppose that the blocks are 12 inches long, and that their thickness is 3 × 2 inches, and that they are all resting on the side, which is 2 inches wide. Now, placed as they are in the group, A will be 12 inches long, whilst the end of each of the blocks B and C, placed at the side, is 2 inches. Thus the width of the front will be 16 inches, whilst the length of the side D is only 12 inches, the length of the block.

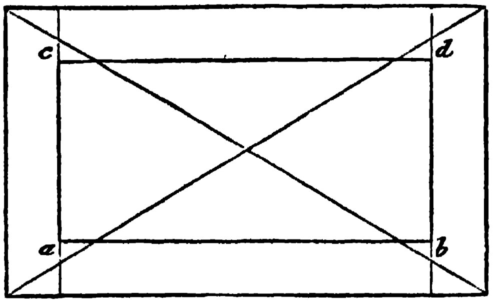


Fig. 17.

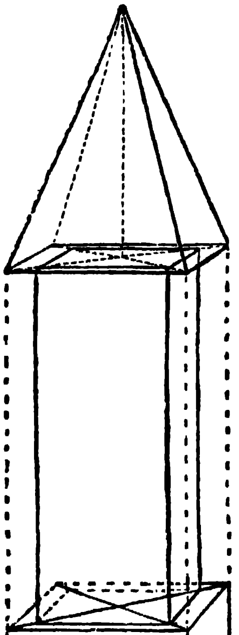


Fig. 18.

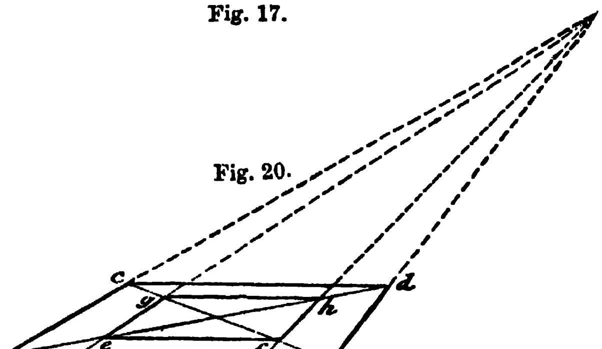


Fig. 20.

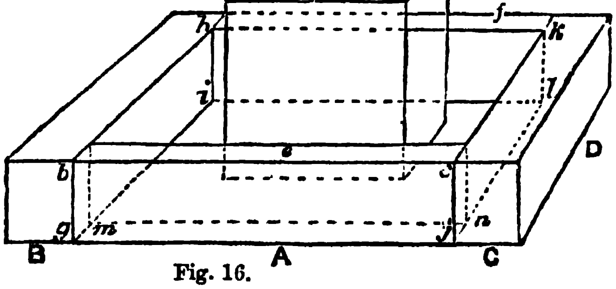


Fig. 16.

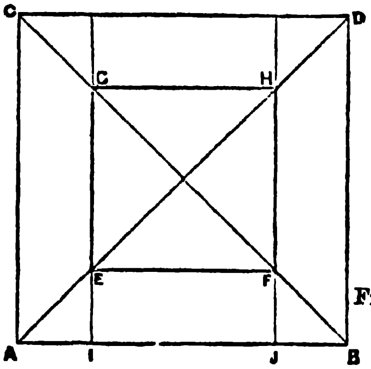


Fig. 19.

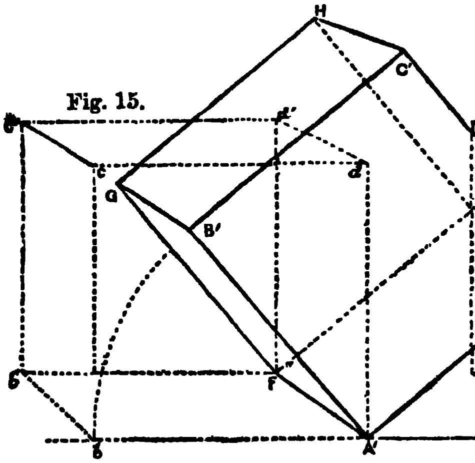


Fig. 15.

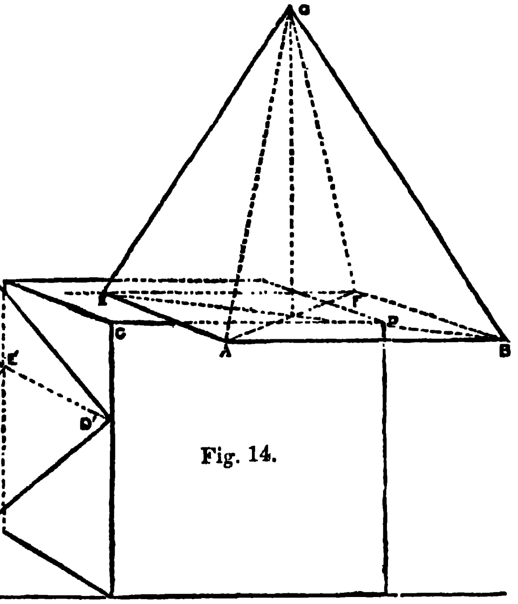


Fig. 14.

In beginning to draw the object thus formed, sketch the entire front, carefully observing the proportion of the blocks.

Next draw the view of the upper surface of the whole object, treating it as a complete block. This surface, it will be remembered, must not be as wide as if the figure to be represented were a square; the side D is then to be added.

Now from *b* and *c* draw lines to the point of sight, in order to represent the inner edges of the two side blocks. If the object were a square, diagonals would now be drawn in the complete quadrilateral representing the top, and the points where *b* and *c* cut these would give the positions of the corresponding lines of the two blocks which are parallel to the picture. This has already been referred to in previous lessons, and will be further shown presently.

This method would not hold good in reference to an oblong, for it will be seen on reference to Fig. 17, that when the four pieces are placed as in the group, the points *a*, *b*, *c*, *d* do not fall in the diagonals.

In object drawing, therefore, the student will, in this case, be called upon to exercise his judgment as to the width of *e* and *f*. It may, however, guide him to be reminded, that in the present view the width from front to back is considerably diminished. The width from left to right retains its true dimensions in the front, and is but slightly decreased at the back. It will be clear, then, that the width of *e* must be rendered less than that of *b* and *c*, and that *f*, being in the distance, must be still further diminished.

From *g* draw a line to the point of sight, and from *h* draw a perpendicular. This will give the point *i*. Then draw a similar line from *j* to the point of sight, and a perpendicular from *k*. This, again, will give the point *l*, and as *k l* is the angle at which the back and right side meet, the line *k l* should be equal to *h i*, and thus a horizontal line drawn from *i* should meet *l*. The rest of the lines required to complete the transparent appearance of the drawing are now to be added; this is necessary since the cube is to be placed in the middle of the vacant space, and it is important to know its position, for if the front line of the base of the cube were placed too far back, it will be clear the cube could not stand in the space, nor can the height of an object which is partially hidden be truly ascertained, unless the obstacles which obstruct the complete view are imagined to be transparent, so that the whole object may be sketched in.

The plan of the cube is now to be sketched in the space *i l m n*, observing that there must be a clear space left all round it, the width on the right and left side being more than that at the front and back. The square for the front is then to be drawn, and the whole cube will then be easily completed.

Fig. 18.—An oblong block, the ends of which are square, stands on the cube. The height of the block here represented is 12 inches, its width being 4 inches. The top of the cube is 6 inches, and thus in the model a margin of 1 inch is left all round. The method of rendering this in a drawing has been before alluded to, but is here given as a separate study, in order that it may be more clearly understood.

Let A B D C (Fig. 19) be a square in which a smaller square, E F H G, is inscribed. It will be seen that the angles of the inner square are on the diagonals of the outer one.

Now, in making a perspective sketch of this figure, draw the line *a b* (Fig. 20) equal to A B, and having drawn lines to the point of sight, draw the back line of the figure, *c d*.

Through the points E, G and F, H (Fig. 19) draw lines meeting A B in I and J. From *a* and *b* (Fig. 20) set off *a i* and *b j*, equal to A I and B J in the previous figure; then from *i* and *j* draw lines to the point of sight, which, cutting the diagonals in *e*, *g* and *f*, *h*, will give the points of the smaller square.

This method is then to be applied in the upper surface of the cube in Fig. 16, and perpendiculars having been drawn from the angles of the inner square, the oblong block may be completed.

A pyramid is now to be placed upon this group, the base of which is larger than the end of the block on which it stands. The lines forming the base of this pyramid being parallel to the edges of the top of the cubical block, the diagonals will coincide.

Now let us imagine *e f g h* in Fig. 20 to represent the top of the oblong block.

Draw diagonals, and produce them beyond the angles of the figure. Then draw the line *a b* at such a distance in front of *e f* as may be required. From *a* and *b* draw lines to the point of sight, cutting the produced diagonals in *c* and *d*. Join *c d*, and this will complete the figure.

In the present study, the base of the pyramid is equal to the top of the cube; therefore, when the diagonals of the top of the oblong block have been produced, perpendiculars raised from the angles of the cube, as shown in the figure, will give the points to which the lines are to be drawn. The cube and pyramid are those shown in Fig. 11, in which it will be seen that the one exactly covers the other; therefore it will be evident that when the pyramid is raised, so long as the edges are kept parallel to those of the top of the cube, the angles of the upper object must be immediately over those of the lower one.

A perpendicular is now to be raised on the intersection of the diagonals; and on this the apex of the pyramid is to be fixed. Lines drawn from this point to the angle of the base will complete the object.

For convenience of reference the enclosure of blocks, the cube, upright oblong block, and surmounting pyramid, have been considered as forming two figures numbered respectively Figs. 16 and 18. It will be useful for the pupil to study and make drawings of these figures separately as well as in combination. In either case the same method must be pursued.

SEATS OF INDUSTRY.—XII.

DUNDEE.—II.

BY WILLIAM WATT WEBSTER.

THE story of the introduction of jute into manufactures is, perhaps, the most interesting episode in the industrial history of Dundee, which has almost monopolised the working of this fibre, at all events up to the present. Dundee has been called "Jutopolis" by some of her citizens, and her claim to the title cannot be disputed. Towards the end of the last century the East India Company sent specimens of a variety of fibres to this country, in order to ascertain whether any of them could be used as a substitute for hemp, and in the lot was included a quantity of jute, which, however, attracted no attention for a considerable time after its arrival. It was at Abingdon, in Oxfordshire, a town noted for sacking and twines, that this fibre is understood to have been first spun into yarn and worked into carpets. In the year 1822, Mr. Thomas Neish, a Dundee merchant, received a small consignment of jute from London, but failed in his efforts to induce the manufacturers to make an attempt to spin it; and after the parcel had been kept for a few years, it was sold to be made into door-mats. About two years later a few bales of the new fibre were sent to Mr. Anderson, a Dundee manufacturer; but although he persuaded his mother, who was an expert at the work, to try to spin it, the experiment was a failure, and all that Mr. Anderson succeeded in producing from the material was a coarse yarn that could be partially used for sacking. In 1832 Mr. Neish got another consignment of jute, which was again offered to the manufacturers and rejected. At last, however, he succeeded in inducing Messrs. Balfour and Meldrum to experiment with the new material, and a successful result having been attained, the foundation of the Dundee jute trade was laid. During the first three years after its introduction, jute was uniformly mixed with flax and tow; but by 1835 pure jute yarn was spun and sold. At that time the fibre could be bought for £12 per ton, whereas at the end of last year its price ranged from £19 10s. to £26, according to quality. In a review of the local trade for 1870, the *Dundee Advertiser* gives the following statistics of the imports of jute into Dundee for the five preceding years, and an estimate of the quantity imported last year:—1865, 71,702 tons; 1866, 52,179 tons; 1867, 63,676 tons; 1868, 58,474 tons; 1869, 80,135 tons; and 1870, 81,600 tons. In 1868, 5,437 tons of jute were imported into Dundee direct from Calcutta, and in 1869 the quantity brought into the port had risen to 27,850 tons. Several of the mill proprietors of Dundee are the owners of the vessels in which their jute is imported, and the "East Indiamen" belonging to them form a splendid mercantile fleet. "The employment of steamers to carry the jute *viâ* the Suez Canal," says the newspaper already quoted, "is a new feature in the trade, which has been called into requisition by the small stocks here, but bids fair to displace to a large extent sailing vessels *viâ* the Cape of Good Hope. The extra cost, after making allowance for towing in, insurance, and interest, is scarcely twenty shillings per ton more than by sailing vessels *viâ* the Cape." Regarding the qualities and kinds of the fabrics produced from jute at Dundee, the deliverance of the jury on jute goods exhibited at the International Exhibition for 1862 may be cited:—"It is in Scotland exclusively where goods made from jute represent a large branch of industry. This very cheap raw material is employed there, either pure or mixed, to make ordinary brown cloth, but more especially sacking, packing-cloth, and carpets. The jute yarns used for carpets are of the richest and most varied colours, and are sometimes used with cocoa-fibre. Even the Brussels or velvet carpet is imitated with success, in appearance, if not in durability." The prices of jute carpeting varies from about 6d. to 1s. 4d. per yard. Jute fabrics are exported to the United States, France, Germany, Spain, and several other European countries, and recently a demand has sprung up in Russia for certain of the coarser qualities.

The most extensive manufacturing establishment in Dundee is that of Messrs. Baxter Brothers and Co., the principal partner of that firm being Sir David Baxter, Bart., of Kilmaron—a gentleman distinguished alike for enlightened philanthropy and success in business. Besides a variety of smaller benefactions, Sir David Baxter has founded several scholarships and endowed a chair of civil engineering in the University of Edinburgh; and about eight years ago he and his sisters presented the town of Dundee with a public park, thirty-eight acres in extent, which cost £50,000, including the embellishments and an adequate endowment for its maintenance. Messrs. Baxter Brothers consume about 7,000 tons of flax annually, and are by far the largest manufacturers of that material in the world. In the spinning department of their works there are some 22,000 spindles, and in the weaving rooms there are about 1,200 power-looms, the motive power being supplied by twenty-two steam-engines, with an aggregate of 750 horse-power. From 4,000 to 4,500 persons are employed by this firm, which produces annually about 20,000,000 yards of various descriptions of cloth, navy sailcloth being the principal fabric they manufacture, and the British navy their principal customer. Excellent school-rooms are connected with the works, to which all the employés have free admission, and a library is also at the service of the workers. The schools have been in existence for upwards of forty years, and the salaries of the master, mistress, and paid monitors, as well as every other expense, have been and continue to be defrayed by the firm.

Messrs. Cox Brothers are probably the next most extensive manufacturing firm in Dundee, about 4,300 persons being employed at their works, which occupy eighteen acres of ground, and are situated at Lochee, one of the suburbs of the town. This firm have agents in Calcutta, and import their jute direct. All the operations of spinning, bleaching, dyeing, weaving, calendering, and packing are completed within their works, which are adorned with a very elegant chimney stalk 300 feet high, and 35 feet in diameter at the base. Messrs. Gilroy Brothers and Co. employ 2,000 persons in their mills, which have a frontage of about a thousand feet, and are the most imposing mill buildings in the town or its neighbourhood. Among the other manufacturing firms in Dundee may be mentioned Messrs. A. and D. Edward and Co., who employ 3,300 persons; Mr. O. G. Miller, who owns five mills, and employs 2,000 work-people; Messrs. J. and A. D. Grimond, and Messrs. Thomson, Shepherd, and Briggs. About ten miles from Dundee, and close to the village of Carnoustie, near the mouth of the Tay, are situated the works of Messrs. James Smieton and Sons, which for various reasons deserve special mention in this paper. This firm only employ about 600 persons, but they have usually some eighty different kinds of cloth in the looms at one time, and they manufacture some five hundred various patterns and fabrics out of flax, tow, and jute. The yearly product amounts to about 5,000,000 yards, and consists principally of "drills," "paddings," and "Russian sheetings" for the United States, West Indies, and Mexico; but "checks" and "stripes" are also made in great variety. It is not, however, for the variety of the fabrics that these works are most noteworthy, but for the institute which the proprietors built in 1864, at a cost of £2,000, and maintain at an annual outlay of £300, for the benefit of their work-people. This institute comprises a fine hall—furnished with a pianoforte and harmonium—class-rooms, library, reading-room, etc., and it has to be added that Messrs. Smieton and Sons have built about eighty dwelling-houses for the accommodation of their employés.

The progress of the port of Dundee has been as remarkable as the progress of her manufactures, and the population has increased in a corresponding ratio. If we may trust Robert Edward, minister of Murroes, who wrote a highly panegyrical and rhetorical description of Dundee in 1678, at that date Dundee was a town of no mean consequence, and had fairly started on a commercial and industrial career. "At Dundee," says this divine, "the harbour, by great labour and expense, has been rendered a very safe and agreeable station for vessels, and from this circumstance the town has become the chief emporium not only of Angus, but of Perthshire. The citizens here (whose houses resemble palaces) are so eminent in regard to their skill and industry, that they have got more rivals than equals in the kingdom." But in 1821, nearly a century and a half later, the population of Dundee had only grown to 30,575, and in 1815 there were but 157 vessels belonging to the port, registering in all 15,275 tons, while 66 vessels entered inwards with cargoes from foreign ports, having an aggregate of 10,620 tons register, and three vessels cleared outwards with cargoes for foreign countries. From the latter date the commerce and population of Dundee have steadily increased, and are still rapidly augmenting. In 1860, 3,130 vessels, representing a total of 396,919 tons burden, were entered and cleared at the port; while in 1861 the population had increased to 90,425, and it has risen during the last decade to about 123,000. It is estimated that since 1815 upwards of £600,000 have been expended on the harbour works, and a project for further harbour improvements, involving an expenditure of about half a million sterling, has been under discussion for several years. Among the minor industries of the town may be mentioned ship-building, machine-making, sugar-refining, and the manufacture of kid gloves, marmalade, and confections.

During the present century the trade of Dundee has passed through many vicissitudes, having been affected for good or for evil by most of the great political events that have occurred throughout the world. The Crimean war brought prosperity to the town, but the American war of Nationality, as the author of the "Biglow Papers" has so happily designated the struggle between the Northern and Southern States of the American Union, may be said to have flooded the town with wealth. Since that very recent date extensive additions have been made to the factories, and mansions and villas have been built in profusion in the suburbs, and in the neighbouring villages on both sides of the Tay. Great improvements have also been effected in the town within the past twenty years, new streets having been formed, and old thoroughfares straightened and widened; but Dundee still abounds in narrow, crooked streets, and a considerable portion of the population still occupy closes where they are "cribbed, cabined, confined," and it would not, perhaps, be a great exaggeration to say that they are "coffined" there as well. But the inhabitants of Dundee, although justifiably proud of the eminent position that the town has attained, are keenly sensible of its defects, and bent upon remedying them. A healthy spirit of emulation pervades the community, which is at once the promise and the guarantee of further progress. The Town Council of Dundee consists of a provost, four baillies, and sixteen councillors, who also act as Police Commissioners; and for years this body has fairly reflected and given effect to the public-spirited enterprise of the citizens. The interests of the staple trade of Dundee are sedulously watched by a Chamber of Commerce, which also criticises and sometimes opposes projects started by the public boards, and in this way it occasionally renders an important service to the inhabitants at large, as well as to the manufacturers. Within a few years a free library has been established in Dundee; the gas works have been purchased for the community; and a splendid esplanade has been constructed on the bank of the river. Dundee abounds in charitable institutions, and contains a very large number of ecclesiastical edifices. The most notable of the former is the Morgan Hospital, a splendid building, in the Scotch baronial style of architecture, which was erected and endowed with money bequeathed to the town by a native who made his fortune in India; and by far the most celebrated of the latter is the ancient tower of St. Mary's Church, commonly called the "Old Steeple," which is said to be nearly eight hundred years old, but which more probably dates from the middle of the fourteenth century, as it is in the Decorated Gothic style, which appears to have been first introduced into Scotland during the reign of David II. Among recent additions to the public buildings of Dundee, the Albert Institute deserves mention. It originated in a desire to perpetuate the memory of the Prince after whom it has been named, by furthering the objects he had most at heart. The Free Library is deposited in this building, and it is proposed that wings should be erected for a public museum and picture gallery. In 1831 the Government, at the request of the inhabitants, granted the town a resident sheriff-substitute, and the Dundee court has for many years been more important than that of the county town. A large proportion of the manufacturers of Dundee have raised themselves from the humbler ranks of industry, and there are few gentry and nobility connected with the town and neighbourhood. Although the merchants and manufacturers possess an elegant Exchange, the majority of them prefer to transact their business *al fresco* on the plain stones of the Cowgate, as their predecessors have done for generations. There are many Irish in Dundee, the majority of whom are Roman Catholics. The condition of the working people generally will compare favourably with that of any other manufacturing town in Great Britain. Dundee is, in short, a fine specimen of a thriving industrial town.

BUILDING CONSTRUCTION.—XVII.

ROOFS (*continued*).

Having the advantage of the co-operation of the heads of various Continental technical schools, we are enabled to introduce several examples used in those institutions, some of which are well worthy of our careful study as well as imitation, and from all of which most important instruction in useful methods of constructing roofs may be derived.

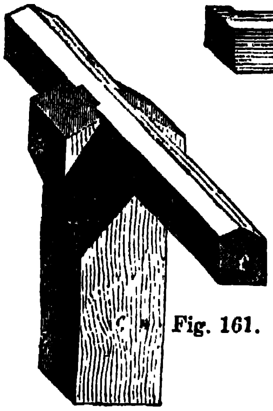


Fig. 161.

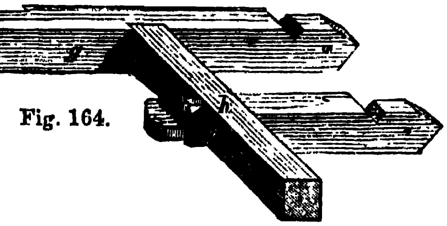


Fig. 164.

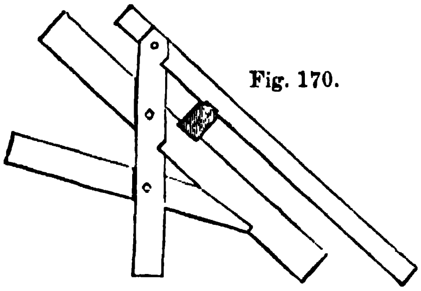


Fig. 170.

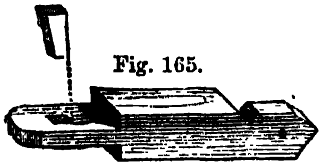


Fig. 165.

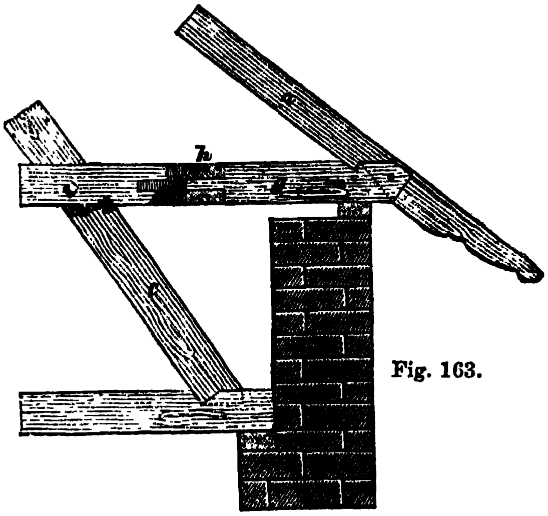


Fig. 163.

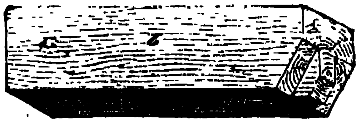


Fig. 162.

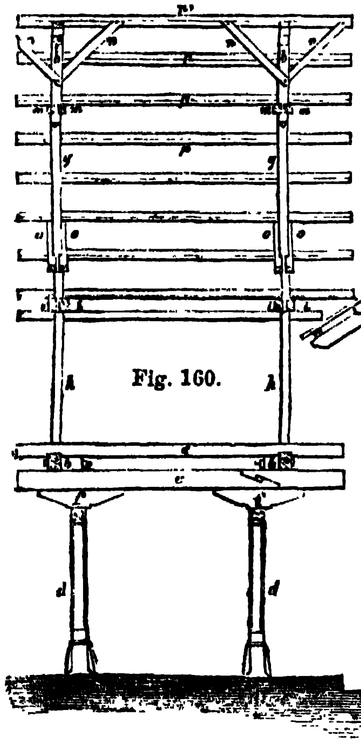


Fig. 160.

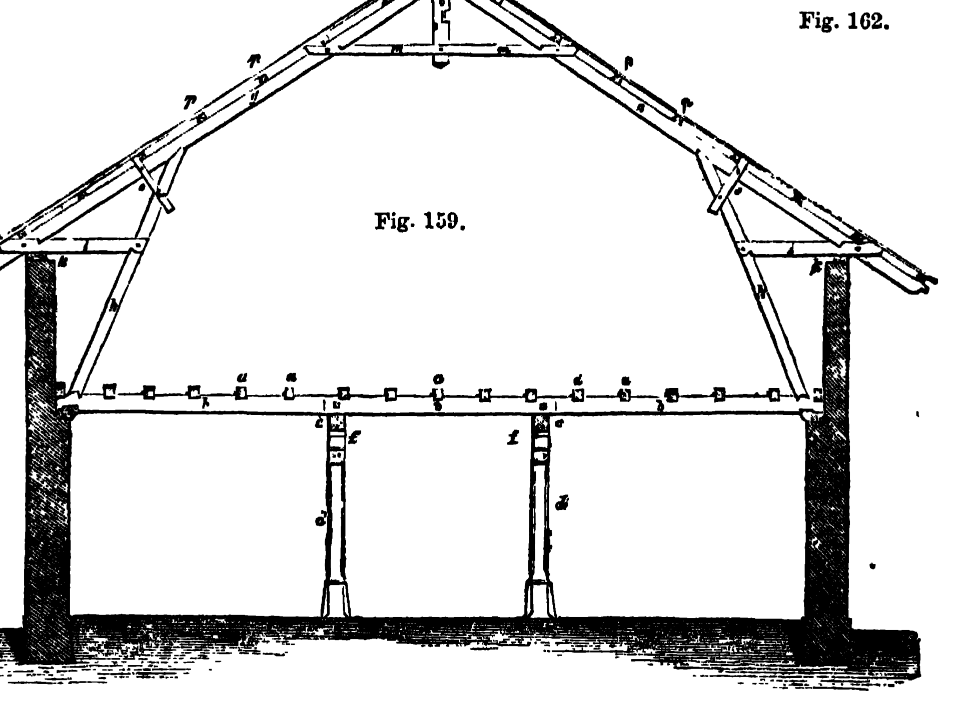


Fig. 159.

Fig. 159 is the transverse section of a German agricultural building, the lower part of which is used as a stable or cattle-shed, and the upper floor as a loft for storage of hay, grain in the sheaf, etc.

It will be remembered that the great object to be constantly kept in view in designing a roof is that its weight must not press *outward*, but *downward*, and this object is best attained by carrying the bearing as low down as possible.

In this example the walls are doubly tied together: first, by means of the tie-beam, which rests on corbels fixed on the lower portion of the wall, which is thicker than the upper. The principal weight of the roof is carried down to this by means of the struts, *h h*, and to these the ties, *o o*, are attached, whilst the cross-pieces act as hammer-beams, being attached at their one end to the struts, and at the other to the end of the principals. The principals cannot thus spread outward, and as the hammer-beams, *i*, rest on the wall-plate *k*, on the upper edge of the wall, a second tie is secured. The principals are further confined at the top by a collar-beam, *m*, suspended from the king-post, *l*. The tie-beam is supported on bridging-joists, which run parallel to the *length* of the building, and are supported on posts, *d d*, the bearing of which is increased by the cross-pieces, *f*, shown in Fig. 160, which is a portion of a longitudinal section, in which will also be seen the method of giving additional support to the ridge-beam by the struts *n*, *n*.

The floor-joists are shown at *a a* and the purlins at *p* in both sections.

Fig. 161 shows the method in which the ridge-tree is attached to the head of the king-post; and Fig. 162 shows the joggle by which the ends of the principals are inserted.

Fig. 163 is a portion of a truss of a similar character drawn to a larger scale. As the trusses must necessarily be several feet apart, the purlins, which are, of course, of a smaller scantling, would be liable to sag. In Fig. 164, therefore, is shown the method adopted for giving support to their ends. This method consists in the placing of additional end-pieces. First, a longitudinal beam, *h*, is fixed at right angles to *g*, and therefore parallel to the wall-plate. The end-pieces are precisely similar in character to the end of *g*, and are inserted into *h* by means of a tusk-tenon wedged in. This is shown in a separate example in Fig. 165.

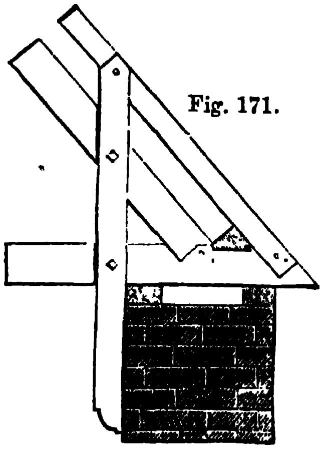


Fig. 171.

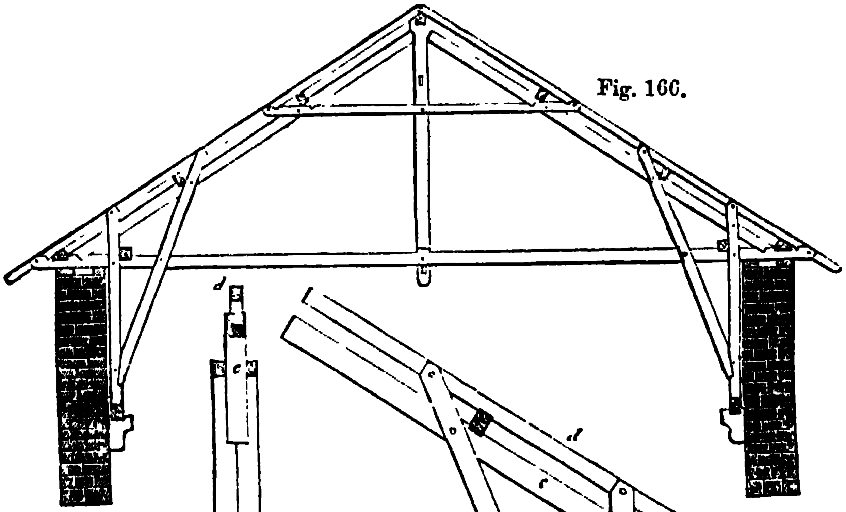


Fig. 166.

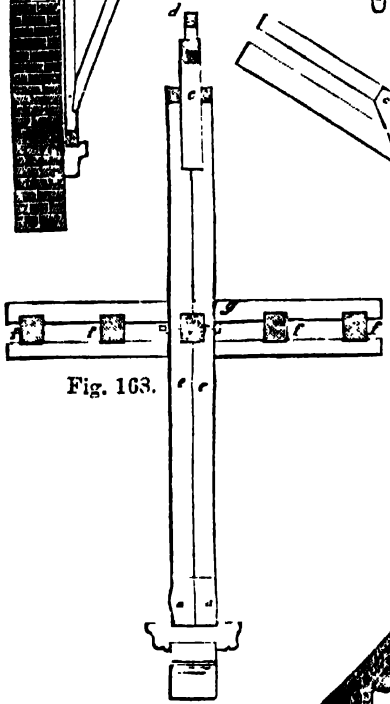


Fig. 168.

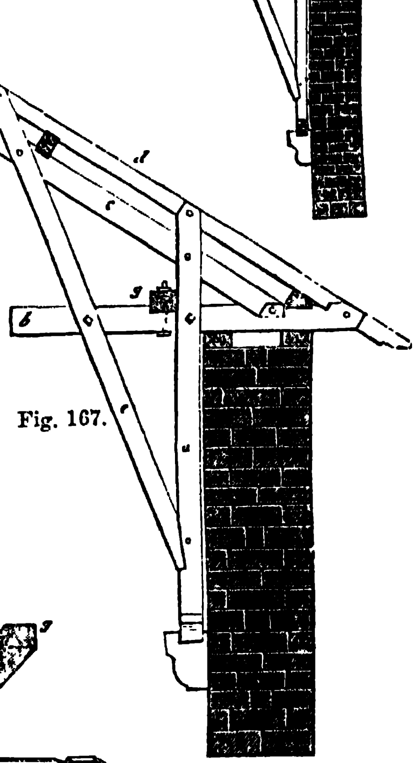


Fig. 167.

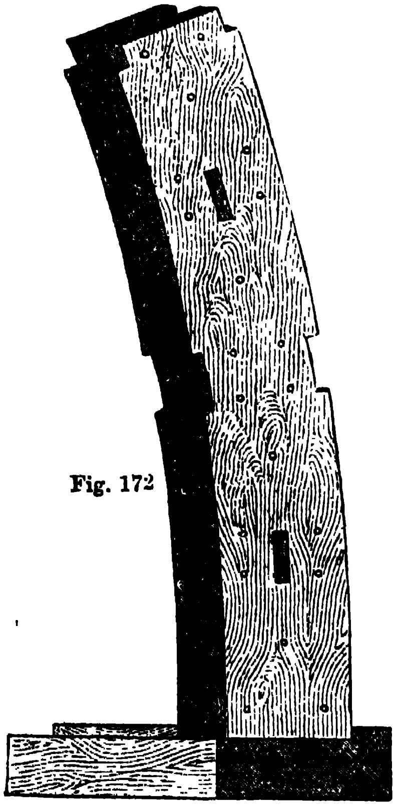


Fig. 172

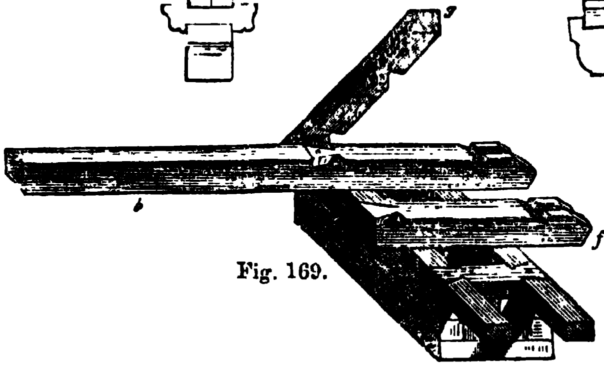


Fig. 169.

As to the mode of drawing this example, the walls should, of course, be drawn first, then perpendiculars for centre-lines for the supporting columns, then the corbels and tie-beam.

It will now be found convenient to draw the section of the wall-plates, the lower line of the principal rafters, the struts *h*, the hammer-beams, the king-post, collar-beam, floor-joists, and then to complete the columns and draw the purlins, etc.

The longitudinal section (Fig. 160) should be *projected* from Fig. 159 by drawing horizontal lines from the edges of the various members shown in the transverse section.

Fig. 166 is the section of a roof in which, although the tie-beam rests on the top of the walls, still the weight is carried downward to a much lower point. This is effected by means of perpendiculars, *a* (see enlarged view, Fig. 167), and struts, *e*, which being double, clasp the tie-beam, *b*, between them, as shown in the enlarged section (Fig. 168), and carry the weight, not only of the principals, *c*, but of the common rafters, *d* (to which it will be seen they are also attached), down to a stone corbel built into the wall; the king-post being also made double, clasps around both tie-beam and collar-beam, and the mutual support thus given admits of timber of smaller scantling, and consequently of less weight, being used. Fig. 169 shows how the double wall-plates are connected by cross-pieces dovetailed into them. The sketch also shows the intermediate end-pieces, *f*, and the manner in which they are secured by the longitudinal beam *g*. Fig. 170 is the elevation of the end of a truss of a similar character, and Fig. 171 is the upper end of a strut clasped by a collar-beam inserted into a principal.

The De Lorme system of building up arched ribs has been alluded to in "Technical Drawing."—IX. (Vol. I., page 135), and it will be remembered that this consists in uniting timbers placed on their edges; these timbers being in short lengths, each cut out of the flat, so as to form a portion of the required curve, the different lengths being united by what is called the "break-joint."

This system has been used more or less ever since its invention. The roof of the middle compartment of the building formerly known as the Pantheon, Oxford Street, London, is constructed on this principle; but owing to the strength of the beams being so much dependent on the lateral cohesion of the fibre, the system has not been generally adopted in roofs, but has on the Continent been used in several large domes. The arch-beams of the original dome of the Halle au Blé, at Paris, built by Messrs. Legrand and Molino, was of this character, but this having been destroyed by fire, has been replaced by an iron one. The span of the original dome at its base was 120 feet. The largest dome in Germany constructed on the De Lorme principle is that of the Catholic Church at Darmstadt, a portion of one of the arch-beams of which is given in Fig. 172. These arched beams, however, do not continuously span the entire well —the diameter of which is thirty-three and a-half metres—but abut at the top against a ring, which is the base of the lantern, or skylight.

The ribs are not all carried up the whole height, but are alternated by narrower ones, which reach about two-thirds of the length of the others, the main ribs being constructed of five thicknesses of timber at their lower half, and of three above the middle—the intermediate ribs consisting of three thicknesses only.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XIII.—JAMES WATT, F.R.S.

BY JAMES GRANT.

JAMES WATT, the celebrated natural philosopher and civil engineer, the narrative of whose life is, in fact, the progressive history of the steam-engine, that most wonderful of all modern inventions, was born in Greenock, by the Firth of Clyde, on the 19th of January, 1736. His great-grandfather, an Aberdeenshire farmer, was killed in battle under the Marquis of Montrose, when fighting for King Charles I. The family from that time became poor, though James, the father of the engineer, rose eventually to be a merchant and magistrate in Greenock, where he died, at the age of eighty-four, in 1782.

James Watt, the oldest and only surviving child (his elder brother John having perished at sea), received his first instructions in reading from his mother, whose name was Agnes Muirhead; but he was taught reading and writing by his father. He was afterwards placed at the elementary public school of Greenock; but the delicacy of his health prevented a regular attendance at classes, hence the greater portion of his time he had to devote himself to unaided study in his own room. His love of mechanics was shown in his youth early, and even as a boy he began to consider with interest and thought the mighty power of steam, as the following perhaps somewhat hackneyed anecdote may serve to show:—

When seated one evening at the tea-table of his aunt, Mrs. Muirhead, after silently observing him for some time, she said, "James, I never saw sae idle a bairn. Take a book, and employ yourself usefully. For the last half hour you have not spoken a word, and have done nothing but take the lid off that kettle and put it on again, or holding a silver spoon over the steam, watching it rising from the spout, and then counting the drops of water."

It would seem that while thus reproved for apparent idleness, the mind of the future engineer was thoughtfully considering the fact of condensation of steam. Every branch of science, as he approached manhood, he prosecuted with equal success; and, among others, took such interest in physic and surgery that he was one day discovered—to the intense dismay of his mother—conveying secretly into his room the head of a child, which had died of some unknown ailment, that he might dissect it.

A growing desire for improvement in mechanics induced him, in his nineteenth year, to visit London, where he placed himself under the care of Mr. John Morgan, a nautical and mathematical instrument-maker, whose premises were in Finch Lane, Cornhill; but in 1756 ill health compelled him to return home. His London experience, brief though it was, enabled him to pursue his studies without more instruction; hence in the following year he started in business at Glasgow as a maker of mathematical instruments. Some of the city trade corporations now attacked him legally, on the plea that he was infringing their privileges; but the professors of the University were so pleased with his skill and application that the Senatus took him under their protection, and assigned him apartments within their ancient college, where he could work unquestioned, as mathematical instrument-maker to that body. Those who most actively befriended him on this occasion were Dr. Dick, Professor of Natural Philosophy; Robert Simson, M.D., Professor of Mathematics; Dr. Black, Professor of Anatomy, the discoverer of latent heat; and Adam Smith, the author of "The Wealth of Nations," then Professor of Logic. For six years James Watt resided in the University, and during that time his shop became the daily resort of the most eminent men in Glasgow; and there many of the most difficult questions in literature, art, and science were discussed, to the advantage of all.

It is recorded as a proof of Watt's singular ingenuity that, though destitute of all ear for music, and unable to distinguish one note from another, he undertook to construct an organ, and actually built one, which displayed many improvements in mechanical details, "in the regulators and mode of measuring the force of the wind, and one, too, which showed no deficiency in its powers of harmony."

In the year 1764 he married his maternal cousin, Miss Miller, having in the summer of the year previous removed from the University into the city; and from thenceforward, aiming at a more ambitious career, he began to turn much of his attention to the improvement of the steam-engine.

In 1761 and the year following he had already tried some experiments on the power or force of steam in a Papin's digester, and had worked with strong steam a little model engine of his own construction; but its many imperfections prevented him at the time from proceeding with it further. It chanced that in the autumn of 1763, Professor John Anderson, who then held the chair of natural philosophy (the future founder of the famous Andersonian Institution), employed Watt to put in order a working model of a steam-engine upon Newcomen's construction, with which he was wont to instruct the students of his class.

At that time the usual practice was to condense the steam in the same cylinder as that in which the piston worked; but this cylinder, being of cast metal, was at every stroke cooled down nearly to the temperature of the water employed for condensation of the steam, hence causing the waste of all the heat requisite for giving the cylinder again its necessary temperature. After many experiments or trials, the happy idea occurred to Watt of saving all the waste of heat and fuel by condensing the steam in a separate vessel, exhausted of air, and kept cool by injection; while between it and the cylinder a communication was to be opened each time the steam was to be condensed, while the cylinder itself was to be kept perpetually hot. On perfecting this great improvement he constructed an entire model, and the success of the experiments made with it placed the advantages of the invention beyond all doubt.

This model has ever since been preserved in the University of Glasgow. In the course of his trials with it, he ascertained to a nicety the exact proportions between water and steam, and also the quantity of water which the heat disengaged by condensing steam would elevate to the boiling-point. On Watt mentioning this discovery to his friend Dr. Black, the latter explained to him his doctrine of latent heat, to the support of which Watt had the pleasure in future years of contributing his experiments.

Want of funds for a time prevented him from continuing his machinery upon a larger scale, but for two years after the discovery his mind was occupied almost exclusively by this desire. However, about 1768, Dr. John Roebuck, of Sheffield, famous as an experimental chemist and metallurgist, and as the improver of the blowing apparatus, having commenced his great establishment of the Carron Iron Works, agreed to speculate with Watt upon being admitted to two-thirds of the invention. Prior to this proposal Watt had been fast losing heart. We are told that he "was a sickly, fragile man, and a constant sufferer from violent headaches; besides, he was by nature timid, desponding, painfully anxious, and easily cast down by failure. Indeed, he was more than once on the point of abandoning his invention in despair."

Aided by Roebuck, he now constructed an engine on a large scale at Kinneil, near Borrowstownness; but pecuniary difficulties on the part of the doctor and increasing engagements on the part of Watt delayed for a time the progress of the work. The latter had now entirely relinquished the business of mathematical instrument-maker, and commenced that of civil engineer. In 1767 he was employed on a survey for a junction canal between the Forth and Clyde, by what was called the Lomond passage, but the bill was lost in Parliament. His next survey was for the Monkland Canal, which was commenced in 1770, and has undergone many improvements since 1792. It is twelve miles long, thirty-five feet wide at the top, and twenty-six at the bottom, with six feet of water.

Many plans of a similar nature occupied his attention till 1773, and surveys and estimates were made by him successively for improvements in the harbours of Ayr, Port Glasgow, and Greenock; for the deepening of the Clyde, improving the navigation of the Forth and Devon; the cutting of a canal from Campbelltown to Machrihanish Bay; of another between the Grand Canal and the harbour of Borrowstownness; the erection of a bridge at Rutherglen, in 1775, another at Hamilton, etc. He surveyed the district of the Caledonian Canal, with plans and sections, which proved of vast use to Mr. Telford, when at a future time that great engineer carried out the works upon a larger scale. To facilitate those surveys, Watt used a new micrometer and a machine for perspective drawing, invented specially by himself.

The year 1769 saw him fully secured by patent in his "improvement for saving steam and fuel in steam-engines;" and having prevailed upon Dr. Roebuck, now by luckless speculations involved in ruin and penury, to transfer all his interest in the said patent to Matthew Boulton, of Soho, in Staffordshire (a village of which that gentleman was the founder), Watt entered into partnership with him, and removed to Birmingham about 1774, a year after the death of his first wife, who left him a son and a daughter. As success in life flowed in upon him he never forgot his gratitude to Dr. Roebuck. "I have met with many disappointments," he once wrote to a friend, "and I must have sunk under the burden of them if I had not been supported by the friendship of Dr. Roebuck."

The patent having been extended to twenty-five years, Messrs. Watt and Boulton now commenced actively at Soho the construction of engines for the drainage of mines, then the chief purpose to which they were applied. These engines speedily came into general use in the mining districts, more especially, perhaps, in Cornwall; and Watt now proceeded to invent still further improvements, all of which he secured by successive patents between the years 1781 and 1785. Among other discoveries were the rotatory motion of the sun and planet wheels, the expansive principle, the double engine, the parallel motion, and the smokeless furnace. The application of the centrifugal regulating force of "the governor" was one of his principal practical improvements; while the perfection to which he brought the rotative engine soon led to its application to every species of mill-work and machinery. But Boulton and Watt were frequently compelled to have recourse to law between the years 1792 and 1799, as several piracies were committed on the rights of their patent.

By this time Watt had re-married, his second wife being a Miss Macgregor, the daughter of an old Glasgow friend.

In 1780 he had obtained a patent for a letter-copying machine, specially his own invention; and in April, 1783, he announced his important discovery of the composition of water, which M. Arago styled "the greatest and most prolific discovery in modern chemistry." His paper on this subject was read before the Royal Society of London, and published in their "Transactions," in 1784. In the following year he was elected Fellow of the Royal Society of Edinburgh, and in 1786 a fellow of that of London.

The winter of that year found him at Marly, whither he had gone at the request of the Government of Louis XVI., to improve the mode of raising water in the famous royal gardens there. It was on this occasion that he won the friendship of M. Berthollet, the eminent chemist, who had recently discovered the bleaching qualities of chlorine. These he communicated to Watt, and the latter, on receiving permission, imparted them to his father-in-law, Macgregor, who was then proprietor of a great bleaching establishment near Glasgow. For this place Watt gave directions concerning the construction of the proper machinery and vessels, superintending the first trials; so he was thus virtually the first to introduce this improvement into Britain.

The year 1800 saw the expiration of his patent, after which he withdrew from the works at Soho in possession of an ample fortune, the just reward of his skill, perseverance, and industry. To his two sons—the youngest of whom, Gregory Watt, had already distinguished himself by literary and scientific talents—he resigned all his interest in the business; but still in retirement devoted a great portion of his time to chemical science, and contributed a paper on the medical qualities of factitious airs to Dr. Beddoes' treatise on "Pneumatic Medicine." He received the degree of LL.D. from the University of Glasgow, in 1806; and eight years after he was elected one of the eight foreign associates of the National Institute of France.

In 1809 his aid was solicited by the Glasgow Water Company to enable them to convey water across the Clyde from a well on the opposite side of the river. For this purpose he formed a flexible main, with ball-and-socket joints, to be laid across the bottom of the water, an idea he derived from observing the structure of a lobster's tail, and in its design and execution the success of the plan was complete. His advice was next asked concerning the formation by Government of new docks at Sheerness, and for his services in this matter he was thanked in 1811 by the Lords of the Admiralty.

In the last year of his long and useful life, Watt was engaged in the construction of a machine for copying pieces of sculpture. He did not live to perfect this clever instrument, for his hands and sight were failing him; but it was so far advanced that he had several models made and given to his friends, as "the attempts of a young artist, just entering his eighty-third year!"

"In his private life James Watt was universally beloved for his genius, esteemed for his benevolence, and courted for the vast range of his information. His conversation was pleasing, abounding with anecdote, and highly instructive. He had read much, and was familiar with several languages. The German he learnt solely that he might peruse Leopold's 'Theatrum Machinarum' in the original."

Among the many inventions of Watt was a tilt-hammer of considerable power. This he first worked by means of a water-wheel, and latterly with a steam-engine regulated by a fly-wheel. His first hammer weighed 120 pounds, and rose eight inches before striking; but he afterwards made one for Mr. Wilkinson, of Bradley Forge, which weighed 7½ cwt., and struck 300 blows a minute. In common with Wedgwood and Sir Humphry Davy, the idea of sun-painting by the daguerreotype had occurred to Watt, who had experimented on the action of light upon nitrate of silver; and very recently, among the old household lumber of his partner, Matthew Boulton, there was found a silvered copper-plate, having on it a representation of their old premises at Soho.

On the 25th of August, 1819, he died, in his eighty-third year, at his house at Heathfield, in Staffordshire, and was interred in the chancel of the parish church of Handsworth, near Birmingham, where a beautiful Gothic monument, with a marble statue by Chantrey, has been erected to his memory. Another marble statue of Watt by the same artist decorates one of the halls of Glasgow University; a third stands in his native town of Greenock; a fourth, of bronze, is in one of the principal squares of Glasgow; a fifth, of stone, is in Edinburgh; and in Westminster Abbey there stands a sixth, of colossal magnitude, by Chantrey, bearing on its base an elegant inscription from the pen of Lord Brougham.

A relic of Watt's skill and industry still exists in his large steam-engine at Carron. It remains in its old position, but is hastening fast to decay. Already the engine-room is crumbling into ruins, and the iron-work is furrowed and blackened by oxidation, as it was abandoned when one of a more improved design was erected about 1740. But as Watt's engine is one of the earliest ever made, and is, as a piece of mechanism, most interesting to men of science, it is much to be regretted that so little care is taken for its preservation.

TECHNICAL DRAWING.—XXXV.

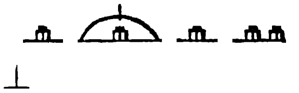
WHITWORTH'S 15-INCH LATHE—(*continued*).

FIG. 347.—The movable headstock and part of bed.

Fig. 348.—An end elevation of the fixed headstock, referred to in the last lesson.

WROUGHT-IRON BOX-GIRDER.

Fig. 349 shows a side elevation and Fig. 350 a section of a girder, such as used for supporting walls for buildings. It consists chiefly of four plates and pieces of angle iron, that are riveted together, forming a very strong box-shaped girder or beam. The plates are cut into proper form by shears, in a shearing and punching machine, and holes are punched for the rivets. In their original form rivets have one head, and when red-hot are put into the holes that have been punched. A heavy piece of iron, technically called a "dolly," is held against the head, while the projecting end is hammered over, and by means of a die made into another head. As the rivet cools, it contracts, and so draws the plates very closely together.



This plan is universally adopted for fastening together the plates for boilers, wrought-iron bridges, roofs, etc., and has the merit of extreme simplicity, combined with durability and strength.

VERTICAL STEAM-ENGINE WITH CYLINDER INVERTED (Fig. 351).

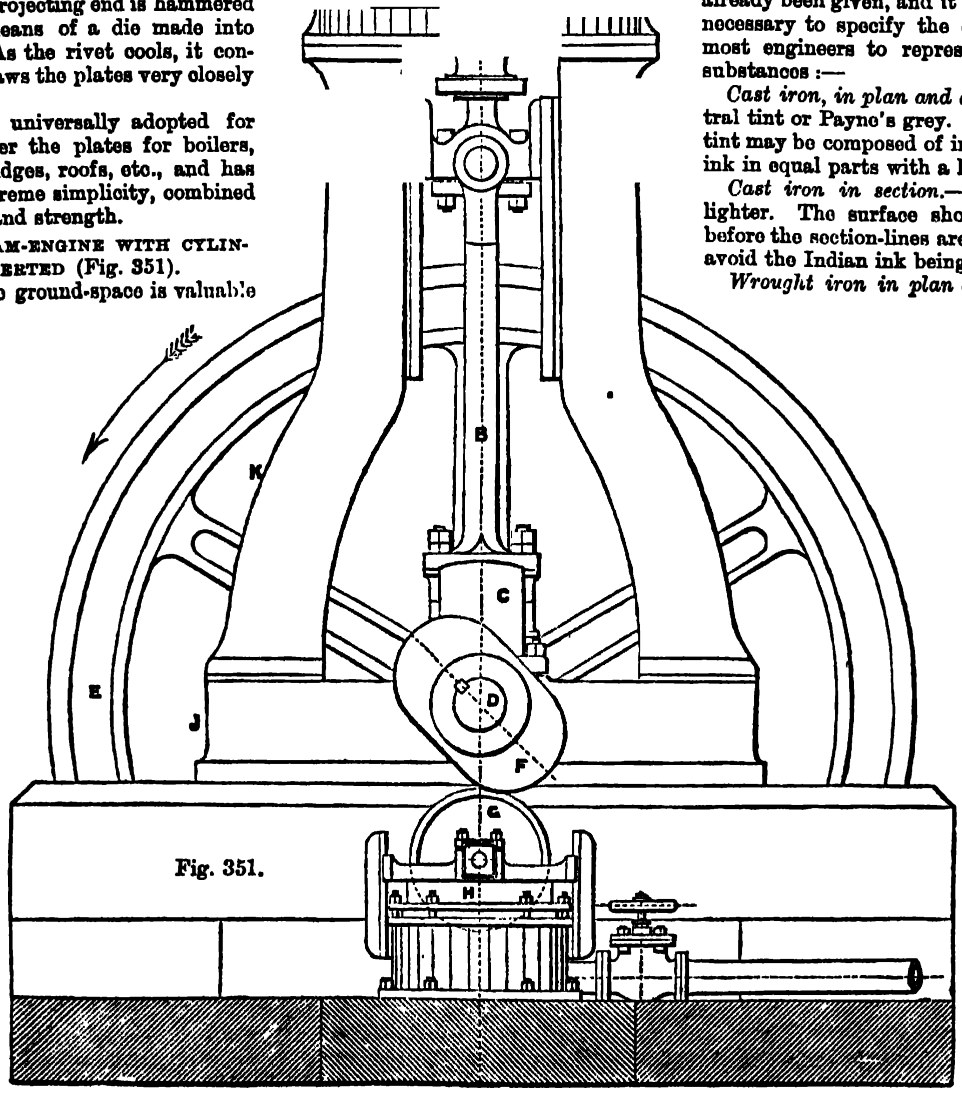


Fig. 351.

In cases where ground-space is valuable this form of the steam-engine is sometimes employed, as it takes up less room than that occupied by the horizontal or beam engine; but it is used most frequently for marine purposes. The cylinder, A, is above, and steam pressure upon the piston inside it produces a reciprocating motion, which, by means of the connecting-rod, B, is communicated to a crank, C, below, and thereby converted into rotation. At the point shown the crank is on the top of its stroke, and as pressure now acts in a straight line between the piston and shaft, D, no motion can take place until the crank has moved sideways a little. When once past this point (called the *dead centre*) the engine-shaft will turn round, and the momentum of the fly-wheel, E, prevents its ever standing fast upon the dead centres. Another plan, recently invented by Mr. A. Rigg of Chester, and Mr. W. Macgeorge of London, for accomplishing this object, is shown in the lower part of the drawing. It consists of a cam, F, keyed upon the main shaft, D, and a roller, G, carried in bearings upon a plunger, H, which has steam pressing underneath it. As shown in the drawing, the steam forces up the plunger and roller, and so turns round the cam, and with it the main shaft and crank. This plan differs from the fly-wheel, inasmuch as it is a real power, which turns the engine round and starts it even if standing (as shown in the drawing), which could never be done by the fly-wheel. It is also much lighter than a fly-wheel, therefore more suitable for ships; and indeed it answers the purpose of a second engine with a crank set at right angles to the one shown. Although both a fly-wheel and cam arrangement are shown in the drawing, only one of them is really necessary, and this drawing forms an example of alternative designs, where two separate or distinct arrangements may be proposed by the designer. In these cases it is usual to make one drawing with ink of a different colour, such as showing the fly-wheel in crimson lake or Prussian blue.

COLOURING DRAWINGS.

The method of colouring drawings has already been given, and it is only therefore necessary to specify the colours used by most engineers to represent the various substances :—

Cast iron, in plan and elevation.—Neutral tint or Payne's grey. A good neutral tint may be composed of indigo and Indian ink in equal parts with a little lake.

Cast iron in section.—The same used lighter. The surface should be coloured before the section-lines are drawn on it, to avoid the Indian ink being washed up.

Wrought iron in plan and elevation.—Indigo.

Wrought iron in section.—The same, lighter, with section-lines.

Steel.—Pale indigo tinged with lake.

Brass.—Gamboge, or Roman ochre, shaded with sepia, which should be done *before* the gamboge is applied.

Copper.—Lake.

Lead.—Pale indigo tinged with Indian ink.

Brickwork in plans and sections.—Lake.

Brickwork in elevations.—Lake mixed with burnt sienna or Venetian red.

Oak or Teak.—Vandyke brown.

Lighter woods—such as fir.—Raw sienna.

Granite.—Pale Indian ink.

Stone generally.—Yellow ochre or pale sepia.

Leather.—Vandyke brown.

Concrete works.—Sepia with darker markings.

Clay or Earth.—Burnt umber or Vandyke brown.

Slate.—Indigo and lake.

In colouring drawings the student should always bear in mind that if any depth of tint is desired, it can only be attained by laying on a succession of washes until the desired tint has been produced.

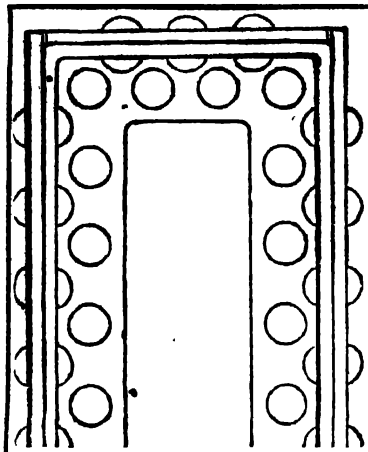


Fig. 349.

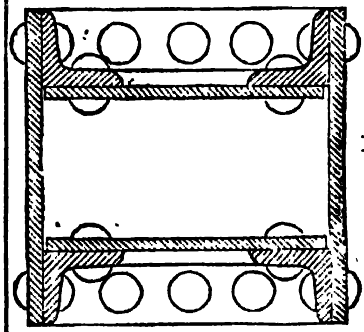


Fig. 350.

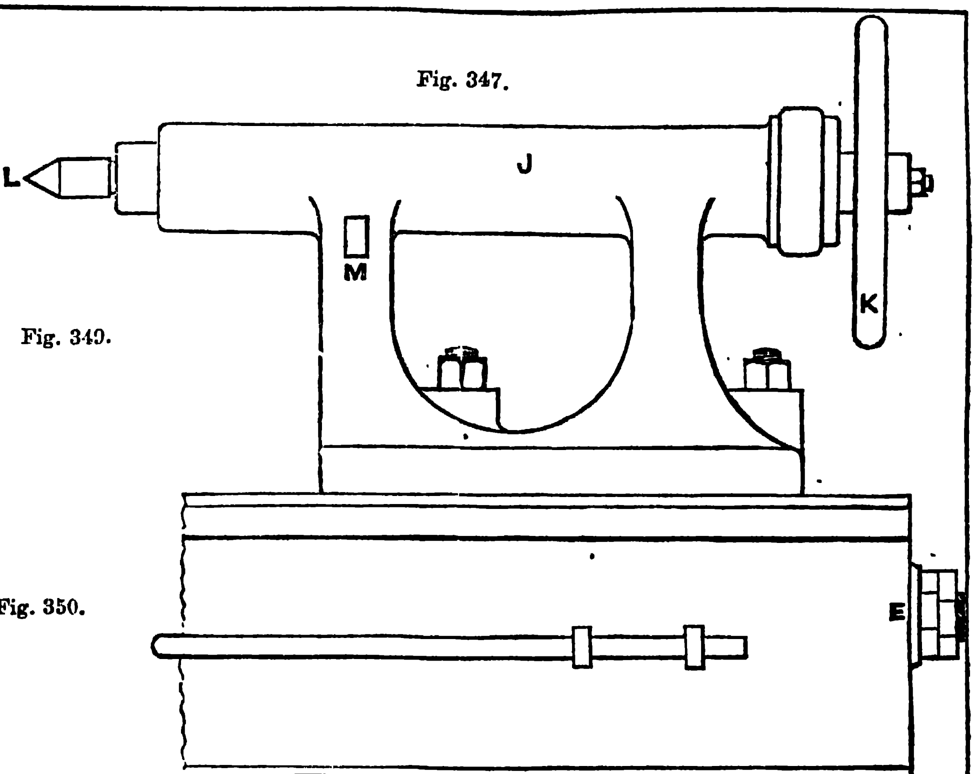


Fig. 347.

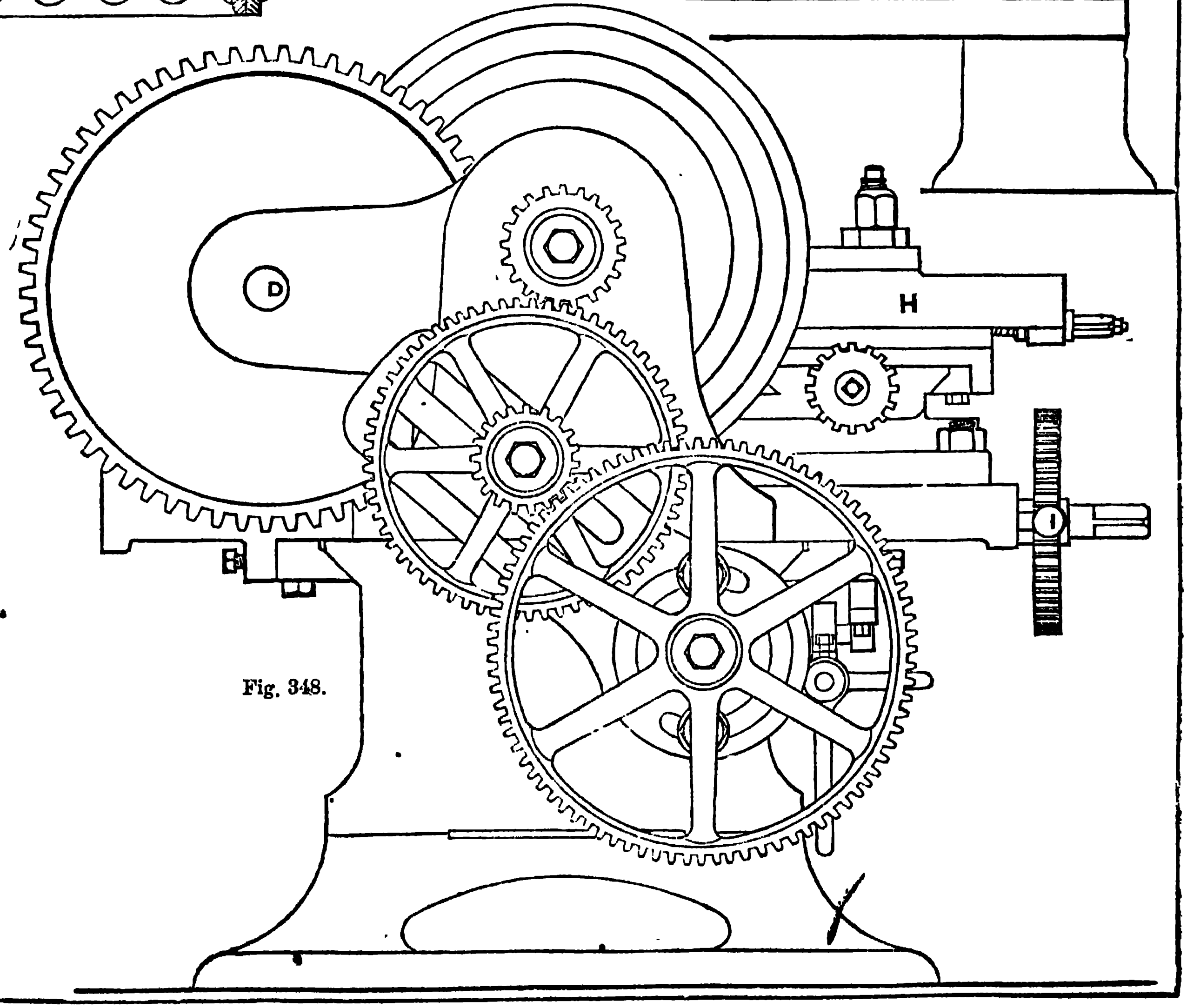


Fig. 348.

NOTABLE INVENTIONS AND INVENTORS.

XIV.—THE SILK MANUFACTURE AND JOHN LOMBE.

BY JOHN TIMBS.

It is a curious fact that all those animals which are most useful to man are likewise most manageable. There is scarcely a caterpillar which is so easily reared as that of the silkworm.

China was, undoubtedly, the country in which men first availed themselves of the labours of the silkworm. Seria (the country of the Seres, whence the rearing of silkworms is called *sericulture*) was a name by which the Macedonian Greeks designated the country which produced the silk that came overland from the north of China. Still, there are reasons for inferring that the culture of the silkworm and the manufacture of silk had not been introduced into India four hundred years after silk was known in Europe. Both the raw material and the manufactured article were obtained in the country of the Thinæ. The Median robes spoken of by the Greek writers of the period of the Persian empire, and extolled for their lustrous beauty and brilliancy, were no doubt silken vestments, and long afterwards, when they had been introduced into Europe, they were called silken. Aristotle is the first Greek author that mentions the silkworm; and he states that the silk was first spun in the island of Cos, but the raw material was still an Oriental product. Pliny states that the silk came from Assyria, and was worked up by the Greek women.* It is probable that silk was in use among the Greeks long before they knew whence the substance came, or in what manner it was produced. Virgil supposed that the Seres carded the silk from leaves; and Dionysius Periegetes also supposed it to be a vegetable product. Thus, he says:—

> "Nor flocks nor herds the distant Seres tend;
> But from the flow'rs that in the desert bloom,
> Tinctur'd with varying hues, they cull
> The glossy down, and card it for the loom."

Pausanias says: "The Seres have a spinning insect, which is kept in buildings, and produces a fine-spun thread, which is wrapped about its feet." It was not until the sixth century that the obscurity which enveloped the subject was cleared up. At this time silk was in general use among the Romans, and was manufactured for them by the inhabitants of Tyre and Berytus, in Phœnicia. The Persians monopolised the supply of the raw material, and guarded their trade both by sea and land, so that travellers from or to China were not allowed to traverse the Persian dominions; and in the time of Justinian the impprtation of silk was entirely stopped. The trade in silk was in this unsatisfactory state when two Nestorian monks of Persia, who had travelled to China, there saw the common silken dress of the Chinese, and the myriads of silkworms on trees and in houses, from which it was obtained. On their return to the West they acquainted Justinian with the mode of producing silk, and undertook to return and bring back with them some of the eggs of the silkworm. This they did, and a quantity of eggs concealed in a hollow cane were brought in safety to Constantinople, and there hatched by the heat of a dunghill, and fed with mulberry-leaves. These worms in due time spun their silk, and propagated, under the careful attendance of the monks, who also instructed the Romans in the whole process of manufacturing silk.

The breeding of silkworms in Europe was for six centuries confined to the Greeks of the Lower Empire. In the twelfth century the art was transferred to Sicily; in the thirteenth century the rearing of silkworms and the manufacture of silk were introduced into Italy, and thence successively into Spain* and France; and in the fifteenth century the manufacture was established in England.

Of all fabrics, that which may be called most historical and of greatest interest to the artist and antiquary is, undoubtedly, silk. Though less early known and manufactured, its beauty is so great and its capacity for fine fabrics so obvious that it has become associated with the ceremonies, splendours, and events of all times—modern times, at least. This costly material, as we have seen, came late to the Romans. From that time it became *the* material for ceremonial dresses, religious and civil; and on all important occasions, down to the costly displays of modern coronations and great Church ceremonies, silk, in the form of tissues, velvets, satins, and the like, has been always in use. The early home of silk, however, has been in the East; and wonderful fabrics are still made in India and Syria with silk mixed with gold threads, beetles' wings, and other decorative substances.

It was not until the reign of Francis I. that the silk manufacture took root in France. At this date Henry VIII. could only obtain a pair of silk stockings from Spain; and the manufacture in England did not make much progress until 1585, when many of the silk manufacturers from Antwerp fled to England from the persecutions of the Duke of Parma, then governor of the Spanish Netherlands. James I. was very solicitous to promote the breeding and rearing of silkworms in England, and had great numbers of mulberry-trees planted for the purpose; the northern side of the site of Buckingham Palace was a portion of the mulberry garden planted by King James. The experiment was not successful, in consequence of our climate being unsuited to the silkworm. James also encouraged the introduction of the silkworm into the English settlements in America. Near the close of his reign, James encouraged a London merchant to bring from the continent of Europe silk-throwsters, silk-dyers, and broad-weavers; and a beginning was made in the manufacture of raw silk into broad silk fabrics, which increased so rapidly that in 1629 the Silk Throwsters of London were incorporated, and the trade had its dye called "London black." In 1661 this company employed above 40,000 men, women, and children. The revocation of the Edict of Nantes by Louis XIV., in 1685, compelled "poor Protestant strangers, Walloons and French," manufacturers and artificers, to emigrate from France in great numbers; when nearly 50,000 took refuge in England, and established such seats of silk manufacture as that of Spitalfields, of the highest style of art and ingenuity of fabric then known, introducing the weaving of lustrings, alamodes, brocades, satins, paduasoys, ducapes, and black velvets. And in 1713 it was stated that silks, gold and silver stuffs, and ribbons, were made here as good as those of French fabric, and that black silk for hoods and scarves was annually worth £300,000. Thus Louis XIV. sent thousands of the most industrious of his subjects into this country, to present his bitterest enemies with the arts and manufactures of his kingdom. Tapestries and hangings for rooms were manufactured in Spitalfields even before the settlement of refugees in that district. In the above year the petition of the Weavers' Company to Parliament, at the Peace of Utrecht, against the commercial treaty with France, represented the silk manufacture as twenty times greater in amount than it had been in 1664; and that it had caused a great exportation of woollen and other manufactured goods to Turkey and Italy, whence the raw silk had been imported.

In the early part of the eighteenth century the Italians exclusively possessed the art of spinning, or, as it is technically called, *throwing* silk; and the British weaver had to import thrown silk at an exorbitant price. In 1702 a Mr. Crotchet had attempted to establish the silk-throwing trade in a small mill which he built at Derby; but from defects in his machinery he was soon compelled to abandon the project. In 1715, John Lombe, whose name will ever be remembered with veneration in connection with the silk trade, visited Italy to acquire a knowledge of its process, with the view of introducing it into England. On reaching Italy, he found the Italians guarded their secret with great vigilance. At Piedmont, finding that he could not examine the silk machinery and its processes, he bribed some of the workpeople; and, by their connivance, in the disguise of a common workman, he made several visits to the mills, and each time carefully noted down whatever he saw, and made sketches of parts of the machinery, so as to perfect himself in the operation of throwing. His stratagem was discovered, and he was obliged to fly with the utmost precipitancy, bringing with him, however, his notes, sketches, and portions of the machinery, and, better still, a mind which had grasped and comprehended the whole process. He fled to avoid assassination, and took refuge on board ship; and returned to England with a full knowledge of the art he had run such imminent risk to acquire. He was accompanied in his flight by two Italian workmen whom he had bribed, and who risked their lives in his project.

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* Pliny, whose judgment and discrimination as a compiler are not greatly to be relied upon, reports that the *bombyx* (or silkworm) is a native of Cos, an island in the Mediterranean archipelago. It is known that silk was manufactured there at a very early period; but Artistotle had previously explained that *bombykia*, or the stuff produced from the *bombyx*, was re-grown, or re-woven by the women of the above island. The inventress of this process was Pamphilia; she unwove the previous material to re-compose it in her loom into fabrics of a more extended texture; thus converting the substantial silks of the Seres into thin transparent gauzes, obtaining in measure what was lost in substance. Attempts have been made to rob the inventress of all the merit belonging to the process by identifying the *bombykia* with the raw material, which it is said Pamphilia and her nymphs procured from Seres, and thus spun or wove into *serica* or silk. But the fact of re-weaving rests upon too good authority to be doubted.—*Encyclopædia Britannica.*

* "The rich and beautiful brocades which adorn some of the Spanish royal palaces, and of which the colours are as fresh as if lately woven, were made many of them a hundred years ago, in Spanish looms. Looms and factories were broken up and demolished during the Peninsular War, and have never since been reconstructed or rebuilt. That war caused, in fact, the total annihilation of the silk trade in Spain—for the little woven in Valencia is scarce worthy of the name—and was the cause of much improvement in French manufacture."—*The Echo*, Jan. 7, 1871.

MINING AND QUARRYING.—V.

BY GEORGE GLADSTONE, F.C.S.

COAL.

VENTILATION — FIRE-DAMP — CHOKE-DAMP — DAVY LAMP — BLIND PITS — THE PIT'S MOUTH — SPONTANEOUS COMBUSTION.

When there are two shafts to a colliery, the one nearest to the dip-head will be the downcast, and that towards the crop the upcast, as the air will naturally tend in that direction independently of any artificial arrangements. The air in the coal-mines is liable to be contaminated with two different gases, known by the miners as fire-damp and choke-damp, the former consisting of carburetted hydrogen, and the latter of carbonic acid. The fire-damp is much lighter than common air, and when mixed with it in the proportion of 1 of gas to 10 of air, it forms a highly explosive compound; the carbonic acid is, on the contrary, heavier than the air, and will extinguish fire, but in breathing it insensibility ensues, and ultimately death. The fire-damp, however, is the principal source of danger. Some seams are very full of it. In the low main of the Newcastle fields, for instance, a miner has been known to come upon a blower giving off 6,000 cubic feet of gas per minute, and these sometimes continue without diminution for months. The fire-damp will not explode if the air is in the proportion of 14 or more to 1 of gas, so that it becomes a matter of calculation as to the rate at which the fresh air should be made to circulate through the mine. It is not found convenient by the pitmen if the current of air exceeds three and a half feet per second, but in the main intake courses it may be increased to four or five feet per second, while owing to the expansion of the air with the increased temperature, and the escape of gases throughout the mine, the velocity in the return main will be very much greater.

In describing the underground plan of a mine a furnace at the bottom of the upcast shaft has been spoken of. It may, however, appear curious that a large fire should be kept burning in a coal mine at the very part towards which the explosive gases are driven. Furnaces at the top of the shaft, with a very tall chimney to increase the draught, have been suggested instead, but the other is more effective. In collieries where there is any reason to fear an excessive quantity of gas the return air-course is not allowed to pass immediately over the furnace, but is carried by a *dumb drift*, A, as shown in the diagram (Fig. 10) in the next page, into the upcast shaft, B, at some little distance above the furnace, the fire in which is fed with fresh air brought in by the air-course, C.

How effective the ventilation is may be judged from the following observations made at Shireoak Colliery, 1,530 feet deep. The temperature of the intake air at the bottom of the shaft was 63° Fahrenheit, and that of the return air 69°; while in a goaf twenty-one feet from the air-current the heat was 72°, and in a close heading 240 feet from the air-course it amounted to 86°. This last is considerably above what it should be, considering the depth of the colliery, but it exhibits the cooling effect of the air-current all the more conspicuously.

In Rosebridge Colliery, Wigan, where two seams are worked, the one 900 and the other 1,800 feet deep, the respective temperatures of the intake and return air at both levels were taken on the 4th of September, 1860, together with the strength of the air-currents and the length of course travelled by them. The temperature of the air in the shade at the surface was on that day 56°, which is above the mean of the year in this climate. That of the intake air at the bottom of the shaft in the upper level was 59½°, and in the lower level 60½°; after traversing 1,000 yards in the former and 1,500 yards in the latter the temperatures were 64° and 73°, the supply of air to the two levels being respectively at the rate of 35 and 81¾ cubic feet per minute. According to our previous estimate, the temperature of the lower level, due to the depth, should be about 81°, showing a reduction caused by the draught of 8°, although, on this occasion, the fresh air poured in was itself comparatively warm. This reduction of the temperature by ventilation has, by the way, been taken into consideration in fixing the limit of coal-mining at about 4,000 feet.

The length of the air-courses in some of the old collieries in the north of England is enormous—even thirty or forty miles—so that the air introduced from above will perhaps be ten or twelve hours before it makes its exit.

In order to diminish as much as possible the risk of explosions, the lamp invented by Sir Humphry Davy, and which bears his name, is very commonly adopted, though not to the extent it ought to be, as the pitmen use naked candles wherever possible, because they give more light. It was found by experiment that fine iron gauze will not allow fire to pass through. The Davy lamp, of which Fig. 11 is a drawing, is therefore made quite air-tight below, while the sides and top are made of a sheet of iron gauze, through which the air required for combustion passes. The oil lamp in the centre is trimmed and lighted before starting, and the gauze cylinder screwed down tight. A is the receptacle for the oil, which is poured in at B, upon which a close-fitting cap is then screwed. C is a metal rod with a claw at the inner end, passing through the oil chamber by an air-tight pipe into the lamp, which is used for trimming the wick, when in the mine, without unscrewing the gauze cover. A gauze containing twenty wires per linear inch will be sufficiently fine for the purpose, though they have often been made much closer. On passing into a gallery where fire-damp prevails, the gas, passing through the meshes of the gauze, will make the lamp burn with increased brilliance; and if the gas is present in any quantity the whole inner surface of the gauze will be covered with a pale blue flame, but it will not communicate with the outside. If the fire-damp should be so abundant as to constitute a third of the volume of the air, it is no longer combustible, and the lamp will go out altogether. This will tell the miner that the atmosphere is no longer fit to breathe. Notwithstanding all precautions, however, the number of accidents is still very large; in 1868 the fatal cases in coal-mines arising from all causes amounted to no less than 1,011, being nearly three for every 1,000 men employed.

Some machines have been invented for cutting the coal, and in the face of such statistics it will be admitted that every appliance which will reduce the manual labour should be hailed as a boon. A variety of patents have been taken out for this purpose, and in some mines they have been successfully used.

When the coal is *got*—that is, broken down from the seam—it is put into baskets or trucks, and conveyed to the main galleries, which are usually laid with trams, and where ponies are frequently employed in drawing the trains of laden trucks to the pit bottom. Unlike the pitmen, who always return to their houses above ground as soon as their day's work is done, these ponies live below, stables being built for them near the bottom of the downcast shaft, so as to afford them as much fresh air as possible.

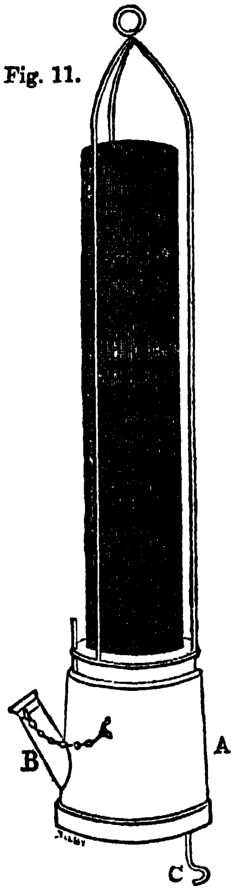
At the bottom of the shaft the coal is transferred to the square tubs, which are made to fit the shaft and run in grooves; when a signal is given to the engineman above, they are rapidly drawn to the surface. The pitmen ascend and descend in the same tubs, but when any of these are coming up, a different signal is given. Iron wire rope is now generally used for hauling, though in some cases flat hempen ropes are employed. The rope is generally wound round a large drum, and is often so arranged that one operation of the engine raises the tub in one segment of the shaft, and lowers the empty one at the same time in the other. By a dial and self-registering apparatus the engineman can tell exactly when the tubs have reached the desired level, a point which it is important he should know when two or more seams are worked from the same shaft.

If the seam, or any part of it, should have a considerable dip, an inclined plane worked by a windlass is substituted for ponies in the main galleries.

More than one seam of coal is often worked from the same shaft. In doing this the distance between them, and the strength of the intervening rock, have to be considered. If a lower seam is worked first, the extent of the operations should be limited so as not to disturb the overlying beds; and where there is any risk of this the upper seams ought to be exhausted first. A mine may, however, be well opened up, leaving large pillars to support the roof while the upper seam is being worked out. For this purpose *blind pits* are very often constructed. They are small shafts, sunk at any convenient part of the workings from one level to another, without being carried up to the surface.

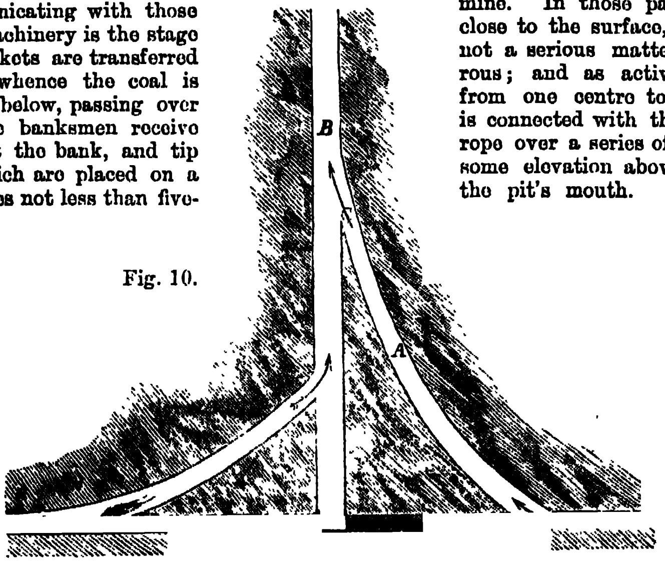
The principal shaft cannot always be sunk at the dip, as there might be a village, or a river, or even the sea in the way. In such cases the drainage water and also the coal as it is wrought will have to be brought uphill to the pit bottom. If the under dip workings are to be carried to any considerable extent, a small high-pressure engine is generally erected at the bottom of the shaft, which pumps the water up to that level, and also draws up the loaded trucks to the same point.

Fig. 11.



We must now return to the surface. The pitmen, when their day's work is over (the work proceeding night and day by relays of men), are rapidly drawn up in the empty coal buckets, which at other times would be filled with coal. Here, at the pit's mouth, is a large establishment—the pumping-engine, which, in a mine that has been extensively opened out, will be kept going constantly; and the winding-engine, connected with the large drum round which the iron-wire rope is coiled, and which is the sole means of communicating with those below. In addition to this machinery is the stage or bank, to which the coal buckets are transferred on arriving at the top, and whence the coal is emptied out into the wagons below, passing over the screens on its way. The banksmen receive the tubs on their arriving at the bank, and tip them up over the screens, which are placed on a slope, having transverse meshes not less than five-eighths of an inch wide, all that passes over such a screen being ranked as large coal. In separating the small from the nuts, screens of three-eighths mesh are used. A line of railway runs just below the lower end of the screens, and the empty wagons are so placed that the large coal passes into them at once. When a sufficient number of wagons are filled, they are sent off to the main line of railway or port of shipment. At the screens boys are employed to watch for any brasses or pieces of slate, which they pick out and throw on one side, such being injurious to the commercial value of the coal. In the large collieries of the north of England the shipping arrangements at the sea-port form a part of the establishment. On arriving at the wharf or staith the bolts which secure the bottoms of the coal-wagons are drawn, and the contents pass through and down a shoot into the ship or barge which lies floating below.

Fig. 10.



The director-in-chief of the mining operations is called a viewer, who has his house and offices near the pit's mouth; the under-viewers have to see that all is going on properly below. The fitter has under his charge the shipment and sale of the coals.

Even when the coal is shipped the risk of explosions is not altogether over. The time being frequently very short between the working of the coal and its being put on board ship, the gas in the lumps of coal has not had time to escape, and if the hatches of the vessel are closed down as soon as the coal is on board, the gas given off, being much lighter than air, will collect immediately under the deck, and find its way out through some little chink between the boards. If this should happen to lead into the cabin, a person going in after nightfall with a naked light would probably be the sufferer by an explosion of sufficient force to blow up all the deck of the vessel. In some ports regulations are made prohibiting the closing of the hatchways for a certain number of hours, in order to allow of the free escape of the gas. There need be no fear of such a disaster after the first day.

Coal is, however, liable to spontaneous combustion. This is generally occasioned by the presence of pyrites or sulphide of iron, which decomposes with the action of the air, and in decomposing a great deal of heat is evolved, sufficient often to set the coal on fire. Coal containing a good deal of small, especially if it be rather wet, is the most liable to this risk. If such a result is feared, the best thing to be done is to turn it over and spread it out as much as possible, so as to let the heat diffuse into the air.

In the foregoing descriptions we have, for the sake of avoiding confusion, taken as our model one of the large collieries such as are to be found in the Newcastle coal-field, except where special mention has been made to the contrary. Coal-mines, however, vary greatly in different parts of the country; many of them are very small, and the whole arrangement of them much simpler. In short, there is every grade, from the open working near Dudley, to the deep and elaborately organised mine. In those parts where the coal seams lie close to the surface, and the sinking of a shaft is not a serious matter, the shafts are very numerous; and as active operations are transferred from one centre to another, the hauling-engine is connected with the new shaft by carrying the rope over a series of wheels, fixed at intervals at some elevation above the ground until it reaches the pit's mouth. In such districts as these, when a fault is reached the work in that pit would be terminated, and a fresh one commenced on the other side of the fault; whereas in a deep mine, if the throw is not very great, a drift would be made through the rock on an incline, and if necessary a blind pit made until the seam is cut on the further side of the fault, when the workings would continue to be carried on from the same centre as before.

Occasionally the seams are tilted up so very much that the pitman stands upon the coal, and has the roof and floor of the bed as walls on the right and left. The shaft is then generally sunk in the seam, and the coal is worked out by running galleries at different levels along the course of the seam. Some interesting specimens of this mode of working occur in the neighbourhood of Edinburgh, where the position of the beds is very much disturbed.

PRACTICAL APPLICATION OF THE FINE ARTS.—II.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

DESIGN.

Pursuing the plan that we have laid out, we will first describe the style of designs suited for a painted window—not that the man beginning, without previous experience in the art, to paint glass will usually be troubled in his early attempts about a design; if he be wise, he will take some design ready to his hand, either suggested by a bit of old glass or copied from a drawing in some of the numerous works which give specimens of work, both ancient and modern, already in existence. Nevertheless, it is advisable even for the workman who not only does not design his own pattern, but even for one who never intends to do so, to have some general notions about the character of the drawing he proposes to use.

Transparency.—The first point to be kept in mind is that the material employed is transparent, and thus differs essentially from the substance of an ordinary picture. This gives the artist a range of colouring, and of light and shade, which is denied to the painter of pictures. At the same time, as glass is necessarily transparent, it will not do to have any portion so dark that it would be entirely devoid of transparency. In fact, the amount of light to be transmitted through the window is a very important consideration. If the building possesses but few and small windows, it will not do to exclude much of the small portion of light admitted; and on the other hand, should the amount of light entering be considerable, deep-coloured and low-toned windows not only conduce to that "dim religious light" which adds mystery and variety to colourless architectural forms, but they are exceedingly agreeable to eyes wearied with the garish light of the everyday world.

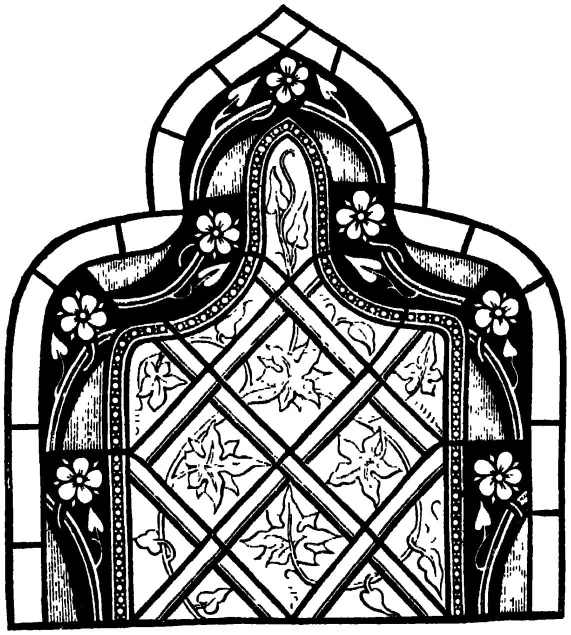


Fig. 1.—WINDOW IN PAINTED GLASS.

Adaptation to Site. — The character, then, of the edifice must be consulted, and it is no less necessary to adapt the designs in the windows to the style of the architecture. What would be pleasing in a Gothic building, would be ridiculous in a Renaissance edifice; and what would be suited to the lancets of an Early English chancel, would be incongruous in the large lights of a Perpendicular west window. A study of ancient glass, therefore, in connection with the architecture of the period, is essential to the perfection of designs for ecclesiastical windows at least, which form a very considerable portion of the whole number of works of this kind.

Another consideration that must enter into the calculations of the designer, is the aspect and situation of the window. In a window looking northward, a predominance of blue will be avoided, and more ruby and orange yellow will be allowable than if the outlook were in an opposite direction. Glass for a clerestory, or other high window, would naturally be of a different style, and ought to be more boldly executed than one which was intended to be placed at a short distance from the eye of the spectator. The ancient designers of glass, like the ancient painters, were not above calculating the effects produced by the probable position of the beholder, so that in a window which could only be looked at from some way below, the faces and limbs were lengthened to a most unnatural extent, in order that when foreshortened by the eye they might appear of a natural proportion. Such artifices must still be adopted if windows are in very awkward positions.

Bad Drawing not necessary to Good Glass.—Though in all these matters the work of old masters not only deserves study, but is absolutely essential to the production of good work, there is one point upon which it is necessary to guard the lover of the antique. No worship of mediævalism will excuse an imitation of the bad drawing and the false anatomy of ancient pictures. The painters of the present day, however much they may study and benefit by the instruction derivable from the works of the veritable Pre-Raffaelites, are not often guilty of the anachronism of imitating their drawing, so defective from a want of knowledge of anatomy. It is surely the part of a wise draughtsman to know how to "reject the evil and to choose the good," amid the varied riches left by the great but human giants of old time. The forms should be not only as good and as true as our present knowledge can make them, but they should also be pleasing; and this is the more necessary in glass-painting, for from the nature of the material the outlines are more strongly marked than they would be in the kindred art of painting or even in many cases of sculpture.

Geometrical Patterns.—But whilst thus only giving general hints and recommendations of study of the best models as the best, and in fact only, preparation for producing designs for those portions of windows that represent figures and scenes, we must remember that there are portions which are easier of accomplishment, more frequent in their occurrence, and about which it is possible to give more definite instruction. Some coloured windows are formed entirely of, and few are completely free from, patterns conveying pleasurable feelings of colour, form, and shade, but not intended to represent action or emotion. Many of these are made up of simple geometrical figures, and in most cases the greater the simplicity, the better the effect; but conventional forms of leaves and other natural objects, or of architectural ornamentation, are intermingled with a portion of arabesque in almost all windows containing human figures.

Example of Pattern.—A first attempt at glass-painting can scarcely be made with a better subject than we give in Fig. 1. Here the design is exceedingly simple and yet very effective. In the first place there is a tolerably wide margin of (so-called) white glass round the outside. The colour of this and of the quarrels in the original window is a light bluish-green, somewhat of the pleasing tone to be seen on the hedge-sparrow's egg. The longer slips between the diamonds are of rather a browner tinge, still very pale, transmitting a considerable amount of light through the whole window. The little beading parallel to the edge of the window is a dull yellow, corresponding to the tinge upon the stalks in the running pattern. This latter is evidently produced by the stain of silver (which will be explained hereafter). It will be seen on close examination that this broader ribbon of colour is made up of nearly triangular pieces fitted end to end, so that the two together make a rather long oblong piece. One of these triangles consists of a deep and bright green glass, scarcely shaded at all. The other is evidently originally of (so-called) white glass, on which the stems are stained (*i.e.* yellow), and the rest of the forms are marked out by very deep shades of brown, thus allowing the eye to suppose that the green is carried on beneath the stalks, which could not have been done, as will be seen hereafter, without great labour and a large quantity of leading. Thus the leading and the shades combine to carry out the forms intended, and with very simple shapes of glass of only two or three colours a most pleasing window is produced. The leaves on the diamond-shaped panes are, of course, formed by shades burnt in, as will be described hereafter.

It should be remembered that it is always necessary to have a margin of light-coloured or even transparent glass around the whole framework of the window, as otherwise a portion of the design will be lost whenever the light comes in any direction excepting straight through the opening.

Working Drawing.—When the design is completed or fixed upon, it is necessary to make a working drawing the full size of the intended window. This is usually done in charcoal upon white paper. This material, of course, affords great facility for correction until it is finished and set, and it also is capable of marking strongly the depth of the lines. The French glass painters make their working drawings with black chalk on blue tinted paper, heightening the lights with white chalk. When this working drawing is completed, and the colours denoted either by their names or by small patches of paint, the next step will be to mark in the lines of the leading and the lines of the stanchions. These stanchions are iron bars crossing the window, fastened to and supporting the leading by which the various pieces of glass are kept together. These bars are usually at fifteen inches apart, and are seldom altered unless they interfere greatly with countenances or some other very prominent part of the picture. They then can be turned aside or removed a few inches, but it is astonishing how little the eye marks their interference when they occur at regular intervals. We remember one instance in which a village blacksmith had made his stanchions in zigzags, in order not to disturb a quarry-shaped pattern—a demonstration of rustic taste and skill that deserved encouragement. In some cases even, as in the Savoy Chapel, the stone mullions of a window are allowed to separate portions of outstretched limbs, without giving any feeling of discomfort to the beholder.

Leading.—The arrangement of the leading requires judgment and care. In much of the old glass we see leads running across limbs, faces, and plain surfaces of drapery, and this is imitated by some of those who copy the antique simply because it is old; but as there is every reason to believe that the ancients did not intend their pictures to be thus disfigured, but that these lines are merely the result of fractures, it is scarcely wise of the student of the old masters to adopt a system worthy only of the manufacturer of sham antiquities. Care should be taken then, in marking out the lines for the leading, not to interfere with the outlines of the design more than is absolutely necessary; at the same time it must be remembered that the heavy and thick glass that has to be employed requires frequent support, and that no very long and thin strips should be exposed to the strain from which they are liable to suffer when placed in the position assigned to them. The introduction of frequent folds into drapery, or a deep line of shadow, will often relieve the workman from these difficulties. Here it will be found that a design thoughtfully planned, with well-arranged breadths of light and shade, will already have an advantage in the more mechanical part of the working over a drawing, which will also be inferior to it in the agreeableness of its result, and which errs artistically in what is technically called *want of breadth*, that is, the lights and shadows are too much cut up, causing a spotty appearance.

APPLIED MECHANICS.—XIV.

BY ROBERT STAWELL BALL, M.A.,

Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.

FLOUR-MILLS.

We propose in the present lesson to inquire into the mechanical principles of that very important class of machines which are employed in crushing or grinding.

The flour-mill has been selected, as being the most important machine of this kind. Flour-mills have received that attention to their mechanical perfection which machines so much used must have necessarily commanded.

The stones which are employed in grinding corn are of a special character. The millstone is a siliceous rock full of interstices or cavities, which retain the grain, and expose it to the action of the revolving stone. The intense hardness of these stones prevents them from being ground away, and having their particles mingled with the flour, as is the case when granite or sandstone, or other comparatively soft stones, are used for the purpose: a good pair of millstones can be used for twenty years. The principal quarry from which good millstones can be procured is at La Ferté, in the basin of Paris. We extract from "Tomlinson's Cyclopædia" the following interesting account of the manner in which these stones are procured. The bed of argillaceous sandstone in which the millstones are found "seldom yields more than three thicknesses of mill-stones; although spread over a considerable plain, it is not always of sufficiently good quality to be worked. The good stone is discovered by sounding. In some places it opens into vertical cracks, which allow the stones to be got out vertically, and these prove to be of the most durable kind. The works are quarries, not mines, for the loose nature of the superposed rock does not allow of the more economical method of driving galleries underground.

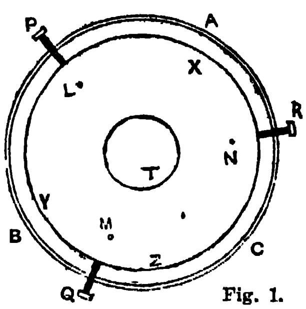


Fig. 1.

"The water, which is rather abundant in the works, is raised by means of buckets attached to balanced levers, which are worked by children, who raise the buckets from stage to stage. When the quarryman has arrived at the bed of millstone, he strikes it with his hammer. If the stone yield a good sound, it is known to be of excellent quality and large size. If the sound be dead or dull, it will separate in getting out. The man then gets out a mass of rock, and shapes it roughly into a cylinder, which, according to its height, will furnish one or two mill-stones; he sometimes gets three, but never more than that number; he then cuts a channel about four inches deep round this cylinder, for the purpose of separating it into two mill-stones, which he does by driving into a channel two rows of wooden wedges, which are gradually and equally driven all round, until the mass splits asunder. The man occasionally applies his ear to the mass, to ascertain that the line of fracture is following the right direction. When millstones of large size are required, the fragments of stone are dressed into their proper shape, cemented together, and united by iron bands. Stones of this kind are largely imported into England and America."

The diameter of the millstones most frequently used is four feet, and their thickness about twelve inches. In the composite stones about half the thickness only is composed of the siliceous millstone, the remainder consisting of plaster of Paris. The lower stone is carefully dressed to a flat surface, but the upper stone is made slightly hollow for a small distance from the central aperture, in order to admit the grain.

The surfaces of both stones are cut into grooves oblique on one side and vertical on the other, so that when the upper stone revolves, the edges of its grooves meet the corresponding edges on the lower groove like a pair of saws, and thus divide the grain. We proceed to describe the manner in which the millstones are mounted, and the mechanical contrivances by which the motion is produced and regulated.

The lower of the pair of millstones is fixed, while the upper rotates. The vertical spindle which turns the upper stone passes through a hole in the lower stone, while the corn is introduced through the hole in the upper stone. We shall first describe the adjustment of the lower millstone (Fig. 1). A B C is the iron case, in which the lower millstone, X Y Z, is placed. The stone is held firmly by the screws P, Q, R. It is essential for the proper working of the mill that the acting surface of the lower millstone be exactly horizontal. This is to enable the pressure of the upper millstone to be perfectly uniform. The lower stone, instead of resting directly upon the bottom of the

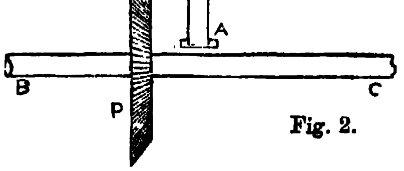


Fig. 2.

case, is supported upon three screws, L, M, N; these screws work in holes, which have been tapped at the bottom of the box. Three points in space determine the position of a plane, consequently even though the lower surface of the millstone be uneven, the upper surface can be made horizontal. The mode in which this is accomplished is as follows:—By means of the set-screws P, Q, R, the millstone is placed perfectly central in the box; a pair of spirit-levels, at right angles to each other, are then placed upon the stone; by means of a spanner, the heads of the screws L, M, N are carefully turned, until the spirit-levels show the upper surface of the millstone to be horizontal. The set-screws P, Q, R are then finally tightened, in order to make the millstone firm, and the setting of the lower stone is complete.

The process here described of adjusting a plane by means of three screws like L, M, N is worthy of attention, as it is of the utmost importance in various parts of mechanics. It should be noticed that less than three screws would not be sufficient, and that more than three would be superfluous.

In Fig. 2 is shown in a diagrammatic manner the relative arrangements of the millstones and the mechanism by which the upper stone rotates. H is the lower stone, A T is the vertical spindle passing through H, which turns the upper stone M. B C is the shaft by which motion is communicated to the different pairs of stones throughout the mill. The fly-wheel of the engine which turns the mill is usually toothed, and gears into a pinion upon the shaft B C. If the mill be worked by water-power, then the shaft B C receives motion from a pinion, which is turned by a large toothed wheel on the axle of the water-wheel. This shaft communicates motion to each pair of millstones by the pair of bevelled wheels P, Q. The wheel P being larger than Q, the vertical spindle is made to rotate more rapidly than the shaft B C. Thus, if the wheel P has three times the diameter of Q, the vertical spindle will rotate three times as fast as the shaft B C. When a pair of millstones is to be thrown out of gear, the pinion Q is raised until its teeth are free from the wheel P. In order to allow of the sliding movement of the pinion upon the vertical spindle, the pinion is not keyed to the spindle. The nature of the connection is shown in Fig. 3. A represents the pinion seen from above. S is a ridge on the boss of the pinion, which fits into a corresponding groove in the shaft P; thus the pinion is free to slide up and down along the shaft, though when the pinion revolves, it must carry the shaft with it. A ring underneath the pinion, which can be raised or levelled by a screw, enables the machine to be thrown into gear or out of gear with facility. We shall presently see that the power possessed by the spindle of sliding through the pinion is of importance, for a more important object than that of a disconnecting gear.

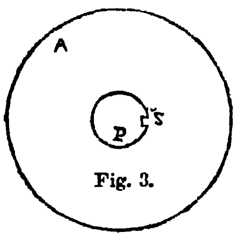


Fig. 3.

A (Fig. 2) is the step in which the lower end of the vertical spindle works. The upper bearing of the spindle is fixed in the lower millstone. The upper end of the spindle is not rigidly attached to the upper millstone. In fact, the upper millstone is attached by a kind of universal joint. Through the end of a spindle is a cross-piece T; the ends of this cross-piece are cylindrical. The bearings of these cylindrical ends are in a piece, K. Even this piece is not rigidly attached to the millstone. The cylinders R X, attached to K, work in bearings on the millstone. Thus the millstone is capable of rotating slightly about either of two horizontal axes at right angles, and therefore of rotating about any horizontal axis. By this ingenious arrangement the utmost facility is allowed to the upper millstone of adjusting itself, so as to work as smoothly as possible over the lower stone.

PRACTICAL PERSPECTIVE.—X.

It is intended in this lesson to show the method of putting into perspective the same object when its sides are placed at angles to the picture-plane, as shown in Fig. 48.

As the vanishing-points will in the present study extend far beyond the limits of the page, a diminished copy (Fig. 49) of the first working lines is given as a guide in starting. The lettering in this corresponds with that of the larger figure.

Having drawn the picture and horizontal lines, the line of direction, C S, etc., construct at S the angles C S C′ and B S B′, corresponding with the angles C A C′ and B A B′ in Fig. 48.

Produce the lines of the angles so as to meet the horizontal line in VP1 and VP2, and find the measuring-points, as already shown.

Proceed to project the square plan of the block by means of the vanishing-points and measuring-points, as in previous figures, and thus obtain the figure A B′ D C′. Draw the diagonals C′ B′ and A D, and produce the latter until it meets the horizontal line in the *vanishing-point for the diagonal*, V D. And now all the lettering will refer to Fig. 47.

From A set off E, and from B set off F, equal to the length which the plinth projects beyond the upper block. From E and F draw lines to the measuring-points, cutting A B′ in E′ and F′. From E′ and F′ draw lines to the vanishing-points, cutting the diagonals in *e*, *g* and *f*, *h*. Join these points, and the figure *e f h g* thus obtained will be the plan of the upper block.

At A erect a perpendicular of indefinite height, and on it mark *a*, the real height of the front edge of the plinth.

From *a* draw lines to the vanishing-points, and from B′ and C′ erect perpendiculars, meeting these in *b* and *c*.

From *b* and *c* draw lines to the vanishing-points, intersecting each other in *d*, which will complete the plinth.

On the upper surface of this, draw the diagonals *c b* and *a d*, and produce the latter until it meets the horizontal line in V D.

From *e* in the plan, erect a perpendicular, cutting the diagonal *a d* in *e′*. Then *e′* is the position of the angle of the upper block.

From *e′* draw lines to the vanishing-points, cutting the diagonal *c b* in *f′* and *g′*. From *f′* and *g′* draw lines to the opposite vanishing-points, intersecting each other (on *a d*) in *h′*. This will complete the plan of the upper block, projected on the upper surface of the lower.

Now, on the perpendicular A mark off A L, the real height of the upper block; and from L draw a line to V D, cutting the perpendicular *e e′* in *m*, which will be the *perspective* height of the object.

From *f′* and *g′* erect perpendiculars; and from *m* draw lines to the vanishing-points, cutting the perpendiculars in *n* and *p*. From *n* and *p* draw lines to the opposite vanishing-points, intersecting in *o*; and this will complete the projection of the object in the required position.

EXERCISE 35.

Put into perspective the object shown in Fig. 46, when standing on the right side of the spectator, at a distance within the picture, the front of the plinth to be parallel to the picture. The measurements to be as follow:—Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 18 feet; side of plinth, 8 feet wide and 3 feet high; side of upper block, 6 feet wide and 8 feet high; distance on left of spectator, 4 feet; distance within the picture, 7 feet.

EXERCISE 36.

The same object to be put into perspective, when one side of the plinth is at 40° to the picture-plane. All the other circumstances as to distance on the left or right of the spectator and within the picture to remain the same.

Fig. 50.—The present subject is more an application of the last study than an absolute lesson, and therefore it is not lettered; so that the student may be thrown more upon his own mental resources, and become gradually accustomed to "think out" the working of perspective forms. Unless he does this, the whole of his exertions will end in his copying the diagrams; and then by far more harm than good will have been accomplished. The author has endeavoured to vary the lessons, and urges on the students the importance of *working every example to different measurements and under different circumstances* to those given in the text. It may sometimes occur that one line is absolutely hidden behind another; and the student may find himself in difficulty *if he depend only on the diagram* to know how it is that he gets *two* lines instead of one. He rubs out, repeats his work, and with the same result; the cause being that his object may have been placed $\frac{1}{16}$ of an inch more to the right or left of the centre of the picture, and that then the line previously hidden will become visible, and his result may be just as correct as the example.

Again, teachers who adopt these lessons (written by one who has spent twenty anxious years in teaching the subject) are recommended to use the black-board for general illustration only; but, as soon as the most elementary principles are mastered, to give to the pupils different dimensions and distances to those from which the black-board lesson is worked, explaining at the same time what changes may occur in consequence of the difference of circumstances. By these means the students will learn and become interested in perspective, which otherwise may be found difficult and irksome.

In Fig. 50, then, we give a simple application of the previous studies; for it will be seen that the base is the same as the object which forms the lesson illustrated by Fig. 46. But, as a *third* block is to rise from it, an additional inner figure is required in the plan. And, further, the capital of the pier is only the same subject as the pedestal turned upside down.

Now in this example the upper blocks are not so high as the lower ones, but are of precisely the same *width*, and are therefore worked from the same *plans*.

If they were different in width, additional plans would be required for them. As it is, let the plan be projected of the whole block in the first instance. Then, diagonals being drawn, the widths of (1) the first block and (2) of the pier itself are to be set off on the picture-line within the extreme points of the containing square. Then, from these points, lines drawn from the centre of the picture will cut the diagonals in points which, being joined, will give (1) the plan of the first block standing on the plinth, and (2) the plan of the pier itself.

Now if, as each process is pursued in the figure below the

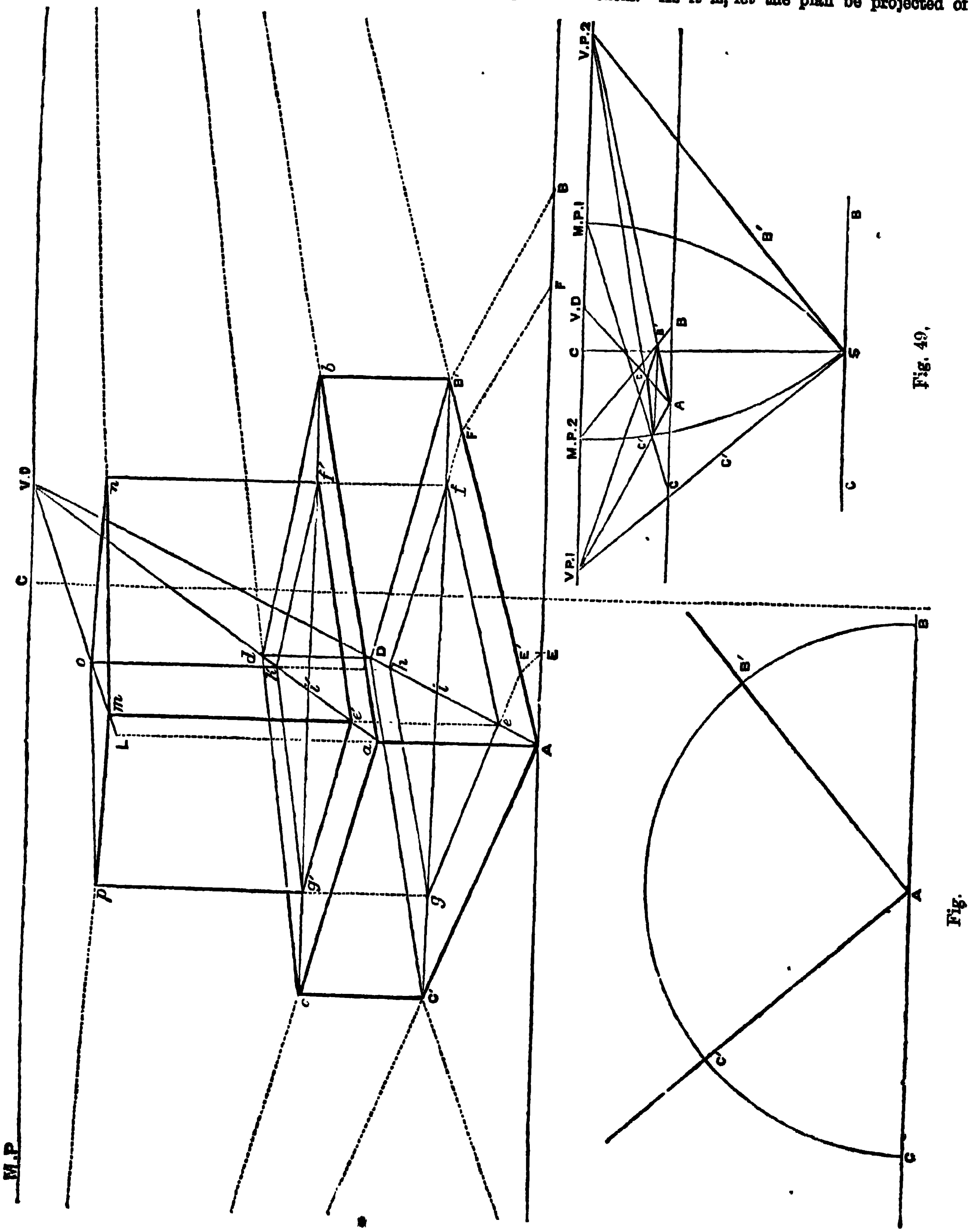


Fig. 49.

Fig.

horizontal line, the same system is followed at the given distance *above*, the corresponding effect will be obtained. Thus, when the plinth has been drawn, the abacus, or upper member of the pier, being the same in every respect but its height, is drawn in precisely the same manner, the lines proceeding to the centre of the picture downwards instead of upwards. And as perpendiculars are drawn from the points in the diagonals on the plan, they will cut the diagonals in the under surfaces of the blocks *above* the horizontal line in the exact points required. In this manner the whole object may be completed.

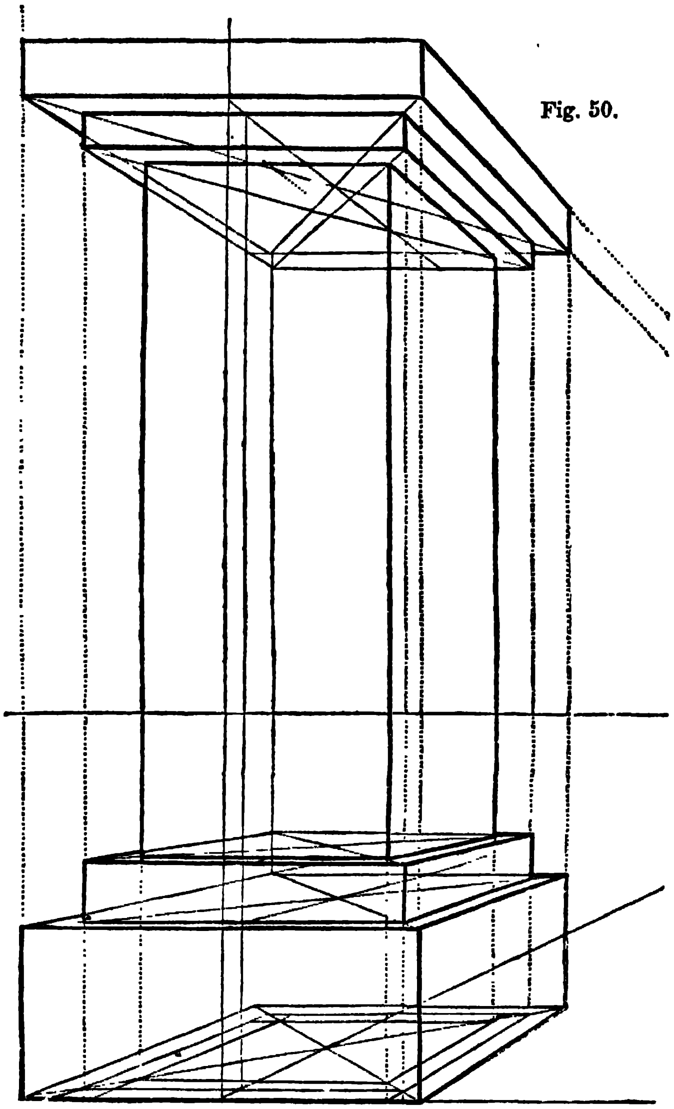


Fig. 50.

Exercise 37.

All the conditions as to height and distance of the spectator being the same as in the last figure, put the same object into perspective, when at a given distance within the picture.

Exercise 38.

Put into perspective the same object, when the sides of the plinth are at 40° and 50° to the picture-plane.

Fig. 51.—This subject is a simple sideboard. It will be seen that the blocks on each side rest on plinths, as the upper block does in the last lesson, and they will therefore be projected in the same way.

The slab forming the top of the sideboard, however, is of the same size as the plinths; and its projection on each side is therefore governed by perpendiculars raised from the angles of the plinths.

When the front edge of the top has been completed, lines are drawn from its extremities to the centre of the picture; and these would be terminated by a horizontal line drawn from A, the point at which a perpendicular raised from the distant angle of the plinth would intersect the line drawn to the centre of the picture.

But this back line would not be visible, since the back of the sideboard would rest on it, and the line which would be seen would be that of the junction of the upright back with the top of the sideboard. Therefore, within the point on the picture-line from which a line was drawn to the point of distance in order to find the distant angle of the plinth, set off the real thickness of the back, and draw a line to the point of distance. This will cut the receding line of the plinth in B; erect a perpendicular at B, and this, cutting the edge of the top in C, will give the place for the back line, C D.

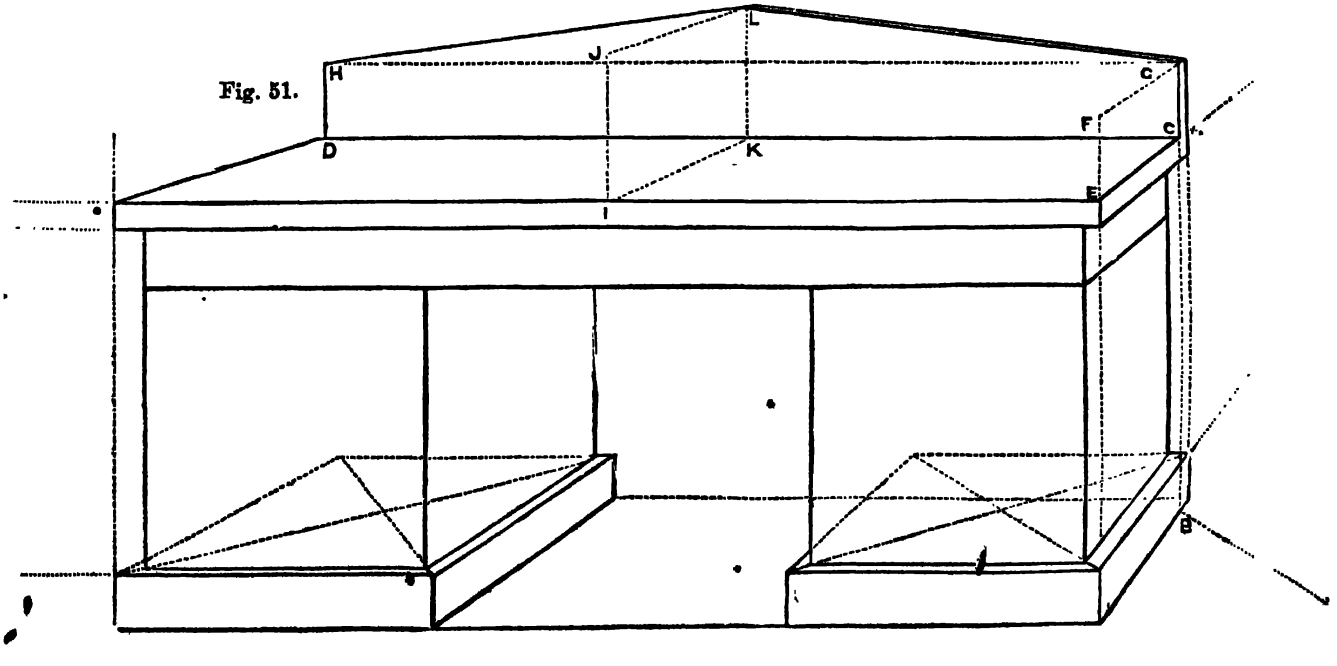
At C and D erect perpendiculars, and at E erect a perpendicular, E F, equal to the height of the back at each end.

From F draw a line to the centre of the picture, cutting the perpendicular at C in G, and a horizontal from G will cut the perpendicular at D in H, the other end of the back.

But the back is not straight, but rises in the middle; therefore, having found I, the middle of the front edge, erect a perpendicular equal in height to the middle of the back.

From I draw a line to the centre of the picture, cutting the back line in K; and at K erect a perpendicular.

Fig. 51.



From J draw a line to the centre of the picture, cutting the perpendicular K in L; draw G L and H L, which will complete the perspective elevation of the back. The detail will be understood without further explanation, and this elementary form may be finished or varied according to taste.

EXERCISE 39.

Put the same sideboard into perspective when standing at a given distance within the picture.

EXERCISE 40.

Put into perspective the same object when standing at a given distance within the picture, its *end* being parallel to the picture-plane.

EXERCISE 41.

Put into perspective the same object when placed so that the front of it is at an angle of 50° to the picture-plane.

EXERCISE 42.

Put the same sideboard into perspective when its front is at 50° to the picture-plane, and when the object stands at a given distance within the picture.

CHEMISTRY APPLIED TO THE ARTS.—X.

BY GEORGE GLADSTONE, F.C.S.

LUCIFER MATCHES.

THOSE who are of middle age will remember seeing in their young days the tinder-box with its flint and steel, and the matches tipped at each end with brimstone—according to the present notions, a very clumsy apparatus for producing a light. The modern lucifer is indeed so vastly more convenient, and has so rapidly displaced the old process all the world over, that the old tinder-box—which was considered so indispensable till nearly the middle of this century—bids fair to be soon entirely forgotten. The lucifer was indeed truly described by the Chancellor of the Exchequer in his recent Budget as "among the most splendid boons—though it sounds an humble thing in itself—which science has given to man."

The remarkable cheapness of their cost tends, no doubt, to very considerable waste in their use, it having been calculated, as far back as 1856, that the daily consumption in Great Britain was about 240,000,000, equal to eight lucifers per day for every man, woman, and child. At that time only about fifteen years had elapsed since their invention. Now that a second fifteen years has passed, the consumption is probably much larger still. During the earlier term four-fifths of the lucifers used in this country were of foreign manufacture, very large quantities being made in Germany. Since then very extensive works have been established in England; and in addition to the home consumption, they form an important article of export to all parts of the world.

The trade may be divided into three principal classes:—1. The wooden match, to which the simple term "lucifer" is ordinarily applied. 2. The vestas, in which a thin wax taper is substituted for the wood. 3. The fusees, which are principally used by smokers for kindling tobacco.

The first is by far the most important manufacture—being twelve times as great as the second and third put together—and will claim principal attention.

The splints of wood are sometimes rectangular, and at other times rounded; the latter having a much neater and more finished appearance. The former are prepared as follows. Soft pine wood is taken and sawn up into blocks of a certain size, so as to fit the splitting machine. The block of wood being then fixed firmly in the proper receptacle, a frame containing a row of sharp-cutting points is, by turning a handle, made to pass over the wood in the direction of the grain, each point cutting into the wood to the depth of about the eighth of an inch. Another motion is then communicated to the machine, which brings a knife-edge against the block, and slices off a layer of the wood to a similar depth. The splints (at that time double the length they are ultimately intended to be) fall down complete into a receptacle below. These alternate actions of the machine continue rapidly, until the whole block is thus cut up.

The manufacture of the round splints may be considered even simpler than the foregoing. The cutting machine consists of a solid plate of metal, which is perforated with round holes as close together as possible, and slightly countersunk in front, so as to present sharp cutting edges. The piece of wood to be operated upon is placed immediately in front of the perforated plate, so that the cross section of the wood rests against it. Pressure is then applied at the other end, and the whole block of wood is ultimately forced through the perforations, coming out on the other side in the form of long thin round pipes, smoothly cut and highly compressed.

The splints are tied up in bundles of a thousand each, and then thoroughly dried by being left in a heated chamber for some time. The next process is ordinarily to dip the ends in melted sulphur, which is commonly done by hand, the dipper giving to the bundle a kind of twist which makes the ends spread out a little, so that they get coated all round with the sulphur, and do not stick together in cooling. Each end is dipped in turn; and when dry the bundles are cut through the middle by a circular saw, thus making them the exact length ultimately required. The object of dipping them first in sulphur is to supply a substance which will readily take fire on the ignition of the compound with which the end is afterwards tipped. The fumes of burning sulphur are, however, disagreeable, and some matches are therefore made without it. In this case the ends of the splints are slightly carbonised by pressing them for a moment upon a plate of red-hot iron, and then just touching them with some melted stearine or paraffin, a small quantity of which is at once absorbed by the wood. These burn even better than the preceding, as the wood then takes fire immediately, while in the others it does not until the sulphur is nearly burnt out. The stearine or paraffin is more expensive, but on the other hand a much less quantity will answer the purpose; and the matches so made are altogether preferable to the consumer.

The next step is to apply the material which is to be the source of fire, and which must be of such a nature as to take fire readily on the use of a moderate amount of friction. We must first consider of what this is composed, and then the manner in which it is applied.

This composition is made up into a pasty mass, the most important ingredient being phosphorus; but both the proportions and the subsidiary articles vary very greatly in different manufactories. The object is to make a paste, which when dried will not be affected by exposure to the atmosphere, which may be readily ignited with moderate friction, and which shall be sufficiently tenacious to adhere firmly to the end of the splint, until the wood has taken fire.

Ordinary phosphorus cannot be preserved in a dry condition in the air, as it rapidly oxidises and takes fire spontaneously, emitting very poisonous fumes at the same time. It has, therefore, to be kept constantly under water, and, except in combination with other substances, would be most unsuitable for domestic use.

Chlorate of potash, which is a highly explosive substance, is free from some of the objections attaching to phosphorus, and it is substituted for it by some makers. Most, however, use a little of each in their paste. The worst feature of the chlorate of potash is its readiness to explode on a very slight concussion, and the violence of its action throwing off sparks, which might prove dangerous. Those containing much of this article may be recognised by the sharp detonation with which they go off; those which are called "noiseless lucifers" contain no chlorate of potash.

These are the two principal light-bearing ingredients. The rest are glue or gum, to give them coherence; some fine sand or pulverised glass, to give increased friction; and some substances which will readily give up a large amount of oxygen, such as nitrate of potash, the peroxides of lead or manganese, and sulphide of antimony, to promote rapid ignition. Some mineral colouring matter is added, according to the fancy of the manufacturer.

It will be quite unnecessary to go into detail as to the relative proportions which may be used, for they may be varied almost infinitely. Even the most important article of all, the phosphorus, varies in quantity from 5 to 50 per cent. The larger proportions are generally to be found in those which contain no chlorate of potash. The lucifers made on the Continent are compounded with gum; but in England glue is generally used, because of the greater humidity of this climate.

The plan adopted in mixing the ingredients is as follows:—The glue is broken into small pieces and put into cold water, in which it is left to soak for some time; it is then boiled up gently until thoroughly dissolved. The pot is then taken off the fire, and the required proportion of phosphorus is gradually added. It melts immediately with the heat of the watery glue, but it must be kept constantly stirred to make it mingle thoroughly, care being taken to keep it below the surface of the liquid. The other articles are then added, and the stirring maintained with vigour, as the compound thickens both with the cooling, and with the addition of the solid ingredients; it must, however, be kept in a pasty condition, and therefore the temperature is not allowed to fall below about 97° Fahrenheit.

The paste is then spread in a thin layer upon a flat table of marble or iron, which is kept just sufficiently warm to maintain the glue in a soft condition, until the dipping has taken place. If gum be used instead of glue, no artificial heat is required at this stage of the process, as it will not solidify by the mere cooling. The paste is spread evenly upon the table to an exact depth, so that in dipping the matches one shall not get a larger share of the composition than another.

The dipping is either done entirely by hand, or with the assistance of a frame. In the former case the workman takes a bundle of splints tied up with a piece of string, and by pressing it between his hands and imparting to it a certain twist at the same time, he makes the heads to separate a little, much in the same way as in the sulphuring process already described, though not to such an extent, as he is now dealing with wood of only half the length. The ends are then brought into contact with the paste, receiving only just sufficient for the purpose of striking a light. Consumers, however, generally prefer those matches which have a good head to them, and as in bundle-dipping they would all stick together if so much of the paste were used, the frame is used in preparing the better class of goods.

The frame or clamp consists of a series of separate pieces of wood fifteen inches long, one inch wide, and a quarter of an inch thick, the under side of which is covered with list, and the upper contains small transverse grooves one-fifth of an inch apart, and just sufficiently large to hold a splint. Children take these pieces of wood, and lay a splint upon each groove, and as soon as one is thus charged they lay the next one upon the top of it, and proceed as before. The list keeps the splints all steadily in their places, notwithstanding any trifling irregularity in their size. When the required number of rows is complete—containing in all about 1,500 matches—the frame which holds them together is screwed tight, and it is then passed on to the dipping department.

The dipper stands at his table of paste, while the frames are handed to and fro by boys. After dipping, they are left to dry for three or four hours in the air, and then are placed in a heated chamber for two hours, the temperature of which is maintained at from 80° to 90° Fahrenheit. The lucifers are by that time finished, and ready for packing, which is done by women and children. In the stoving and the packing great precautions have to be taken against fire. The people are supplied with cisterns of water in which to dip their hands if necessary, and each one has a small box of sawdust in which to thrust any lucifer that may be accidentally lighted.

Some patents have been taken out for cutting, dipping, drying, and packing the matches by machinery; and, independently of economical grounds, it is desirable that manual labour should be saved as much as possible, the work being both unhealthy and dangerous. In the best-regulated establishments these objections are, however, reduced to a minimum; and aggravated forms of the phosphorus disease are becoming very rare.

A more general use of the safety matches would perhaps be the most satisfactory way of obviating every objection, as there is a certain amount of danger attending the use of the ordinary lucifers at all times. If dropped upon the floor they will take fire when trodden upon; and even children have been known to poison themselves by sucking the paste off the ends. The absolute harmlessness of the safety matches is due partly to the use of the red or amorphous phosphorus instead of the ordinary description; and, secondly, to the mode of its application. This variety is not liable to spontaneous combustion; indeed, it will not burn except at a pretty elevated temperature, and it is not poisonous; so that it is free from all risk, both in the manufacture and in the subsequent use. From this description it will naturally be inferred that the action of the red is not so strong, and it is found necessary in practice to use a larger quantity, which considerably adds to the expense, phosphorus of either sort being very dear. A larger proportion of chlorate of potash and of the oxygen-supplying compounds is therefore substituted, if a match is to be made of the red phosphorus, which will take fire on any friction being applied in the usual way; but these are liable to the risk of ignition by friction accidentally applied, which will not occur in the case of the safety match. In these the chlorate of potash and one of the metallic salts is made into a paste with glue, and the match is dipped into it, as already described, while a second paste, consisting of the amorphous phosphorus, some more of the metallic salt, and a little glue, is made, and spread on the rubber in lieu of sandpaper. By thus dividing the ingredients, no action will take place, except on application to the rubber prepared for the purpose.

The vestas—the aristocratic match, as the Right Hon. Robert Lowe called them—are principally to be distinguished by the substitution of a waxed cotton for the wooden splint. The tapers are made by fixing a number of pieces of cotton thread, slightly twisted, in a frame, and then passing them through melted wax two or three times, until they acquire a coating of sufficient thickness; to make the surface of the wax smooth and bright, they are afterwards drawn through a perforated metal plate. The taper being less rigid than the wood, a larger proportion of phosphorus is required to be used in making the paste, so that less force may be needed when rubbing them on the sandpaper.

Fusees have cardboard or paper as a foundation. This is thoroughly saturated first with nitrate of potash; then cut into strips, and the paste applied to the edge by means of a spatula, after which they are laid out on a rack to dry. The nitrate of potash which has been absorbed by the paper, causes it to burn slowly and continuously, even though exposed to a strong current of air.

PRINCIPLES OF DESIGN.—XVI.

BY CHRISTOPHER DRESSER, PH.D., F.S.L.

WALL DECORATIONS (*continued*).

PURSUING our consideration of wall decorations, we notice that, just as the ceiling ornament must accord in character with the architecture of the room in which it is placed, so must the wall decoration be of the same style as the architecture of the room. Indeed, whatever we have said in a former lesson respecting the harmony of the ceiling decoration with the architecture of the building, applies equally to the ornamentation of the wall, if not even more forcibly, if this be possible.

It has been customary to arrange walls into panels when decorating them, and of this mode of treatment we give one illustration (Fig. 49); yet nothing can be more absurd than such a treatment, unless the wall is architecturally (structurally) arched. A wall may be so formed that some parts are thick, so as to give the required strength, while other portions are thin. In such a case the wall would be formed of arched recesses and thickened piers alternately. This being the case, the decoration should be so applied as to emphasise, or render apparent, this arched structure; but if the wall is of one thickness throughout, its division into arches is absurd and foolish.

We sometimes see great follies, and even gross untruths, perpetrated with the view of bringing about the so-called decoration of a room. Thus it is not unfrequently that we meet with imitation pillars, recesses, and arches as the so-called ornamentation of a room.

In low music halls we are not surprised by such decorations, for we do not look for truth or any manifestation of delicacy of feeling in such places. Falsity and the untrue appear in natural juxtaposition with the debased and the vulgar. Sham marble pillars, a fictitious and merely imitative architecture, an assumed and unreal, yet coarse and vulgar gorgeousness, are the natural adjuncts of immorality and vice; but such falsities cannot be tolerated in the abodes of those who pretend to purity and truth, nor in the buildings which they frequent; yet even the new Albert Hall has sham marble pillars (I say this to our shame), and but recently I visited a church near Edgware, in which there is a display of false decoration such as I never before saw. Here we find sham pillars, giving a false

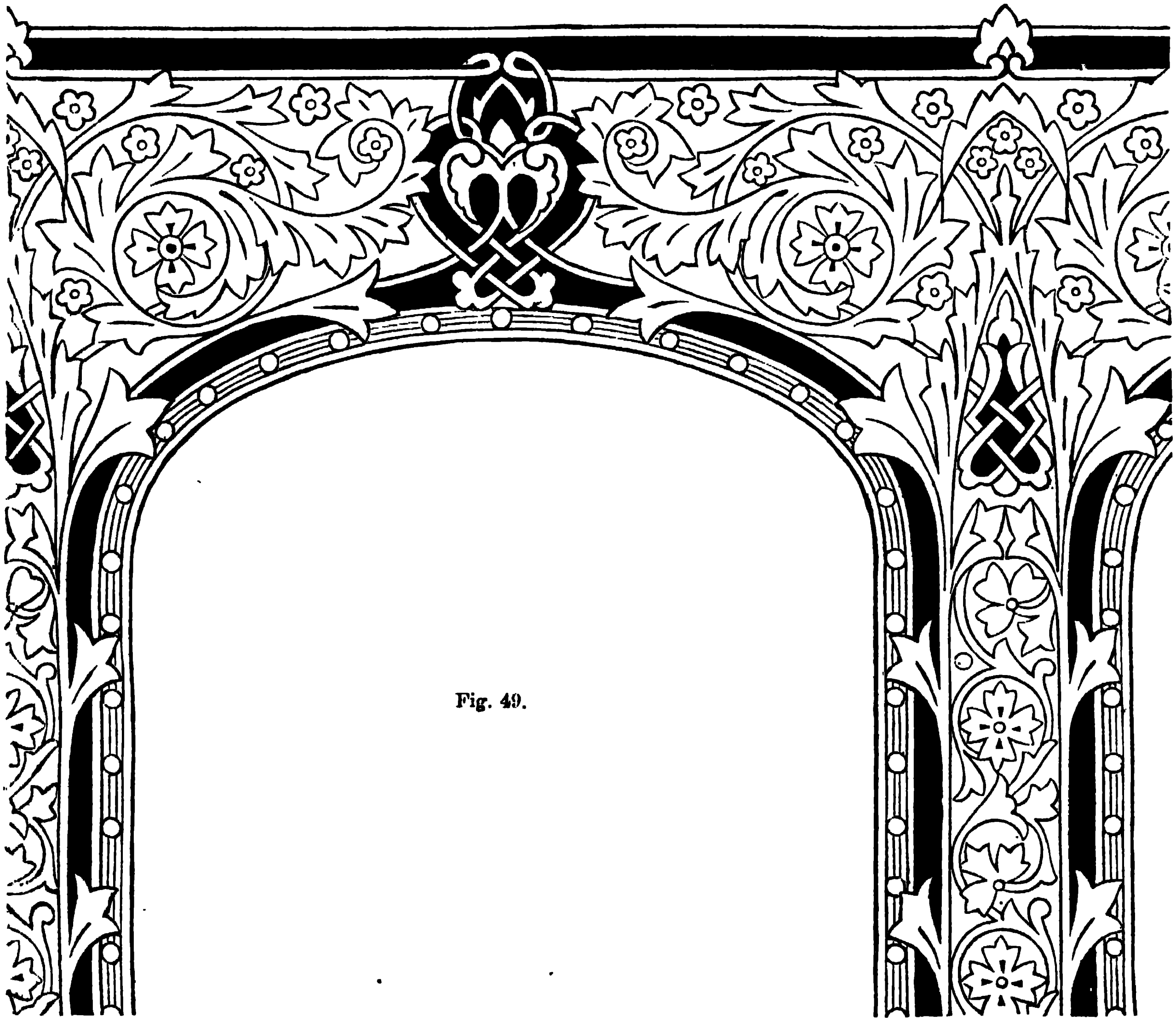


Fig. 49.

architecture; sham niches, containing sham statues; sham clouds, forming an absurd ceiling; and almost every falsity which a falsely constituted mind could perpetrate.

How strange it is that in a church, where purity and truth are taught, the whole of the decorations should be a sham! It is said that if you want to hear a fierce quarrel, and to see true hatred, you must seek it in religious sects and theological discussionists. On the same principle, I suppose, we must prepare ourselves for a display of the worst art-falsity in the sacred edifice. Perhaps the idea is that of contrast. As the teetotal lecturer had a drunken man by him as a frightful example of what was to be avoided, so the decorations of this church may be intended as a warning, rather than as an example of what should be followed. Happily such churches as this are rare, and it can be truly said that ecclesiastical architecture and decoration has made great strides with us in recent years, and that in very many instances it is rigidly truthful as well as beautiful.

Before leaving the consideration of wall decorations, I must object to all imitations, as sham marbles, granites, etc., for no wall can be satisfactory which is to any extent a display of false grandeur; and this is curious, that in many cases it costs more to produce an imitation marble staircase than it would to line the same walls with the marbles imitated. I have known a case in which the imitation has cost double what the genuine stone would have cost, and such a case is not exceptional, for hand-polished work is always expensive. To imitations of marbles and granites, as I have already said, I strongly object, and of the genuine stone I am not fond, unless sparingly and judiciously used. My objections to its free use are these:—1st. Harmony of colour depends upon great exactness of tint. This exactness is rarely attainable in the case of two marbles. One stone may, however, be brought into direct and perfect harmony with a coloured wall, by the tint of the wall being carefully suited to the marble. 2nd. The true artist thinks less of the costliness of the material of which he forms his works than of the art-effect produced. Thus the old Greeks, who were full of art-feeling and refinement, coloured the buildings which they constructed of white marble, and they certainly thereby improved them; for colour, if harmoniously employed, lends to objects a new charm—a charm which they would not without it possess. I must further say, before leaving our present subject, that all walls, however decorated, should serve as a background to whatever stands in front of them. Thus they must retire even behind the furniture by their unobtrusiveness.

The order of arrangement in furniture must be this. The living beings in a room should be most attractive and conspicuous, and the dress of man should be of such a character as to secure this. Ladies can now employ any amount of colour in their attire; but poor man, however noble, cannot by his dress be distinguished from his butler; and, worst of all, both are dressed in an unbecoming and inartistic manner. Next come the furniture and draperies—the one or the other having prominence according to circumstances; then come the wall and the floor, both of which are to serve as backgrounds to all that stands in front of them. In decorating walls, or in judging of the merit or suitability of wall decorations, this must always be taken into consideration, that they are but enriched backgrounds; and it should also be remembered that the nature of the enrichment applied is determined, to a great extent, by the character of the architecture of the building of which the wall forms a part.

We come now to consider wall-papers, which are hangings prepared with the view of enabling us to decorate our walls at comparatively small cost. I may confess that I am not very fond of wall-papers under any circumstances. I prefer a tinted or painted wall. Yet they are largely used, and will be for a long time to come. I have already said in a former lesson that if wall-papers are used they should not be joined together with straight lines, and that we ought to consider them as so much art-material which should be used artistically.

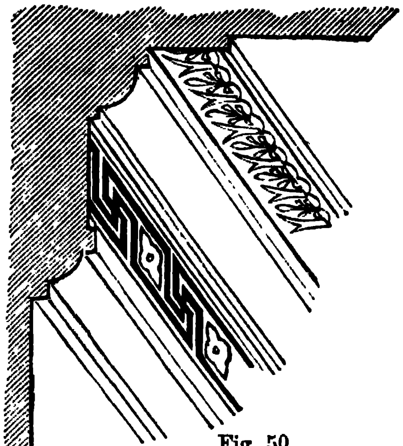


Fig. 50.

As to the nature of the pattern which a wall-paper should have, it is almost impossible to speak, as there are endless varieties; but as a rule it may be said that those consisting of small, simple, repeated parts, which are low-toned or neutral in colour, are the best. Most wall-paper patterns are larger than is desirable. The pattern can scarcely be too simple, and it should in all cases consist of flat ornament.

If the ornament is very good, and the pattern is the work of a true artist, it may be larger, for then the parts will be balanced and harmonised in a manner that could not be expected from a less skilful hand; but even if by the most talented designer, it must ever be remembered that he has designed it at random, and not as a suitable decoration for any particular room. The man who selects the pattern for a particular wall must choose that which is suitable to the special case.

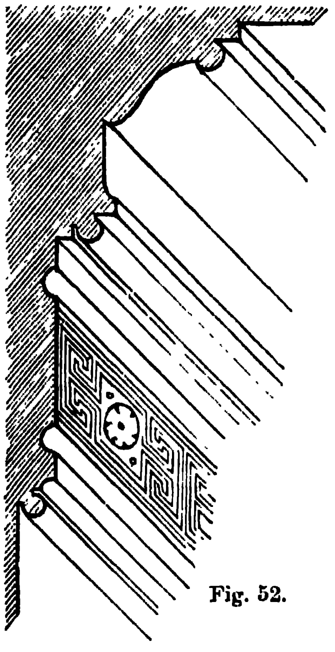
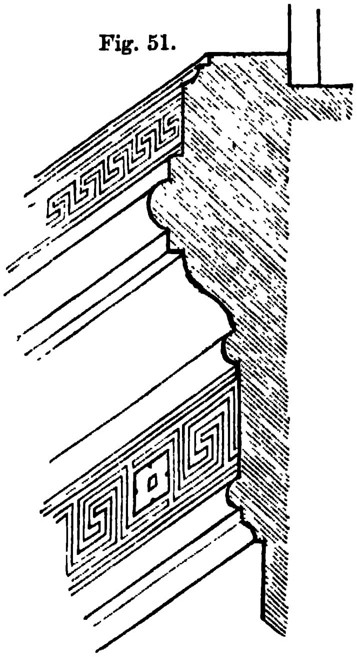


Fig. 52.

The effect of a wall-paper is materially affected by many circumstances. Thus, by the quantity of light admitted to the room, as whether the room is dark or light; by the aspect, whether it receives the sun's rays or does not; by the character of the light, as whether direct from the sky, or reflected from a green lawn, or red-brick wall. All these things must be considered, and what looks well in the pattern-book may look bad on a wall.

The best wall-paper patterns are those which consist of somewhat strong colours in very small masses—masses so small that the general effect of the paper is rich, low-toned, and neutral, and yet has a glowing colour-bloom, but these are rarely to be met with.

It was a fashion some time since to make wall-papers in imitation of woven fabrics, and this fashion has not wholly disappeared yet, absurd though it be. It arose through the accident of a designer of wall-paper patterns having been a shawl-pattern designer, and having a number of small shawl patterns on hand, which he disposed of as wall-paper patterns. A pattern which is suitable for a woven fabric is rarely suitable to a printed fabric, and especially when the one pattern is to be seen in folds on a moving object, and the other flat on a fixed surface. And at all times imitation by one material of another is untruthful, and it becomes specially absurd when we think that almost every material is capable of producing some good art-effect which no other material can. We should always seek to make each material as distinctive in its art-character as we can, and to cause each to appear as beautiful as possible in that particular manner in which it can most naturally be worked.

Fig. 51.


A word should be said about the particular character which a wall-paper pattern should have, but the remarks which I am now about to make will apply equally to all patterns employed as wall decorations. If we view trees or plants, as we see them against the sky as a background, they are objects which point upwards and have a bilateral symmetry (their halves are alike), or are more or less irregular in form, and when seen in this view we may regard them as natural wall decorations. Our wall patterns, then, may point upwards, as in Fig. 47, and be bilateral or otherwise; but it must be remembered that when the flowers of a primrose protrude from a bank, they are regular radiating, or star, ornaments. I think that it is legitimate for us to use on a wall star, or regular radiating, ornaments, as well as those having a special upward tendency.

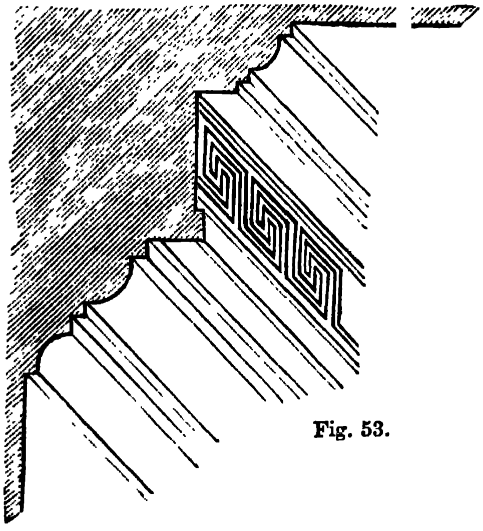


Fig. 53.

I have said that when seen from the side plants are bilateral, or are more or less irregular. As I have referred to plants as furnishing us with types of ornament, I should not be doing rightly were I to leave this statement in its present form, for the tendency of the vital force of all plants is to produce structures of rigidly symmetrical character; but insects, which eat buds and leaves, and blights, winds, and frosts, so act upon plants as to destroy their normal symmetry, hence we find an apparent want of symmetry in the arrangement of the parts of plants.[*]

Respecting the colouring of cornices, a few words should be said. 1st. Bright colours may here be employed. 2nd. As a rule, get red in shadow or in shade, blue on flat or hollow surfaces, especially those that recede from the eye, and yellow on rounded advancing members. 3rd. Use for red either vermilion or carmine; for blue, ultramarine either pure or with white; for yellow, middle or orange chrome, diluted with white. 4th. Use red very sparingly, blue abundantly, the pale yellow in medium quantity.

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[*] Those who seek further information on this subject, will find it in the chapter on the arrangement of leaves, in Dresser's "Rudiments of Botany" (Virtue); Dresser's "Popular Manual of Botany" (Black); or Dresser's "Art of Decorative Design" (Day and Sons).

Besides primary colours, none others need be used on the cornice. It is a mistake to use many, or dull, colours here, but gold may be used instead of yellow. With the view of explaining the principles which we have just enunciated by diagrams, we give four illustrations (Figs. 50, 51, 52, 53), and in a future number we purpose giving a coloured plate illustration of cornice, ceiling, and wall colourings.

NOTABLE INVENTIONS AND INVENTORS.

XV.—THE SILK MANUFACTURE (*concluded*).

BY JOHN TIMBS.

On arriving in England, in 1717, Lombe agreed with the Corporation of Derby to rent on a long lease for £8 a year an island or swamp in the river Derwent, 500 feet long and 52 feet wide. Here he erected, at a cost of £30,000, an immense silk-mill, now the property of the Corporation, the lease having expired. The foundations were formed of oaken piles, 16 to 20 feet long, driven close together by means of an engine which he contrived for the purpose; on these piles was laid a foundation of stone, on which were turned stone arches to support the walls. During the four years occupied in the erection of the mill, Lombe, in order to raise money to carry on the works, hired rooms in Derby, and in the town-hall set up his machines, which were temporarily worked by hand, and by which he was enabled to sell thrown silk at much lower prices than it could be obtained from the Italians. By the time his large mill was completed he had permanently established the silk-throwing trade. In 1718 he obtained a patent, and, with the aid of his Italian workmen, was proceeding successfully in his business, when he died, cut off, as it was thought, by poison, through the agency of an Italian woman, whose business he had drawn away to himself. William Hutton, a native of Derby, whose early days were spent toiling in this very mill, states that Lombe lingered two or three years in agony, from the slow poison; and the woman was interrogated, and suspicion strengthened. He was honoured with a superb funeral. "He was a man," says Hutton, "of quiet deportment, who had brought a beneficial manufactory into the place, employed the poor, and at advanced ages, and thus could not fail to meet with respect; and his melancholy end excited much sympathy."

John Lombe was succeeded by his brother William, who, in a fit of melancholy, shortly afterwards shot himself. About 1726 the mill passed to his cousin, Sir Thomas Lombe, who in 1732, on the expiry of the patent, petitioned Parliament for a renewal, which was declined. The Government, however, granted the sum of £14,000 to Sir Thomas as compensation, on condition that he would prepare and deposit in the Tower of London an exact and faithful model of his machinery, for the inspection and advantage of those who might purpose constructing similar works. The Act authorising the issue of the money mentioned, among other circumstances which justified the grant, the great obstruction offered to Sir Thomas Lombe's undertaking by the King of Sardinia, in prohibiting the exportation of the raw silk which the engines were intended to work.

The accounts of the machinery of this immense mill, five storeys high, have been much exaggerated. The grand machine is stated to have been constructed with 26,586 wheels, and 96,746 movements, which worked 73,746 yards of organzine silk-thread with every revolution of the water-wheel whereby the machinery was driven; and as this revolved three times in each minute, the almost inconceivable quantity of 318,504,960 yards of organzine could be produced daily! Hutton's authority is, however, the best, for he served an apprenticeship of seven years in the mill, and he reduces the number of wheels to 13,384. The whole was moved by one water-wheel. Sir Thomas Lombe is stated by Hutton to have accumulated more than £120,000 by this mill. The chest in which John Lombe brought over to England his spindles and other machinery was long preserved in the mill which he built, but became the property of Mr. Llewellyn Jewitt, F.S.A. The chest is much older than Lombe's time; it is richly carved and painted, and, apart from its association with his name and career, is a remarkably fine example of art. It is engraved with Lombe's Mill, in "Stories of Inventors and Discoverers," 1860. Many throwing-mills have since been erected at Derby, and this branch of industry may be regarded as the staple of the town. Lombe's machinery has not, however, been used for many years; and improved machinery, which performs twice the work in less room, is now adopted.

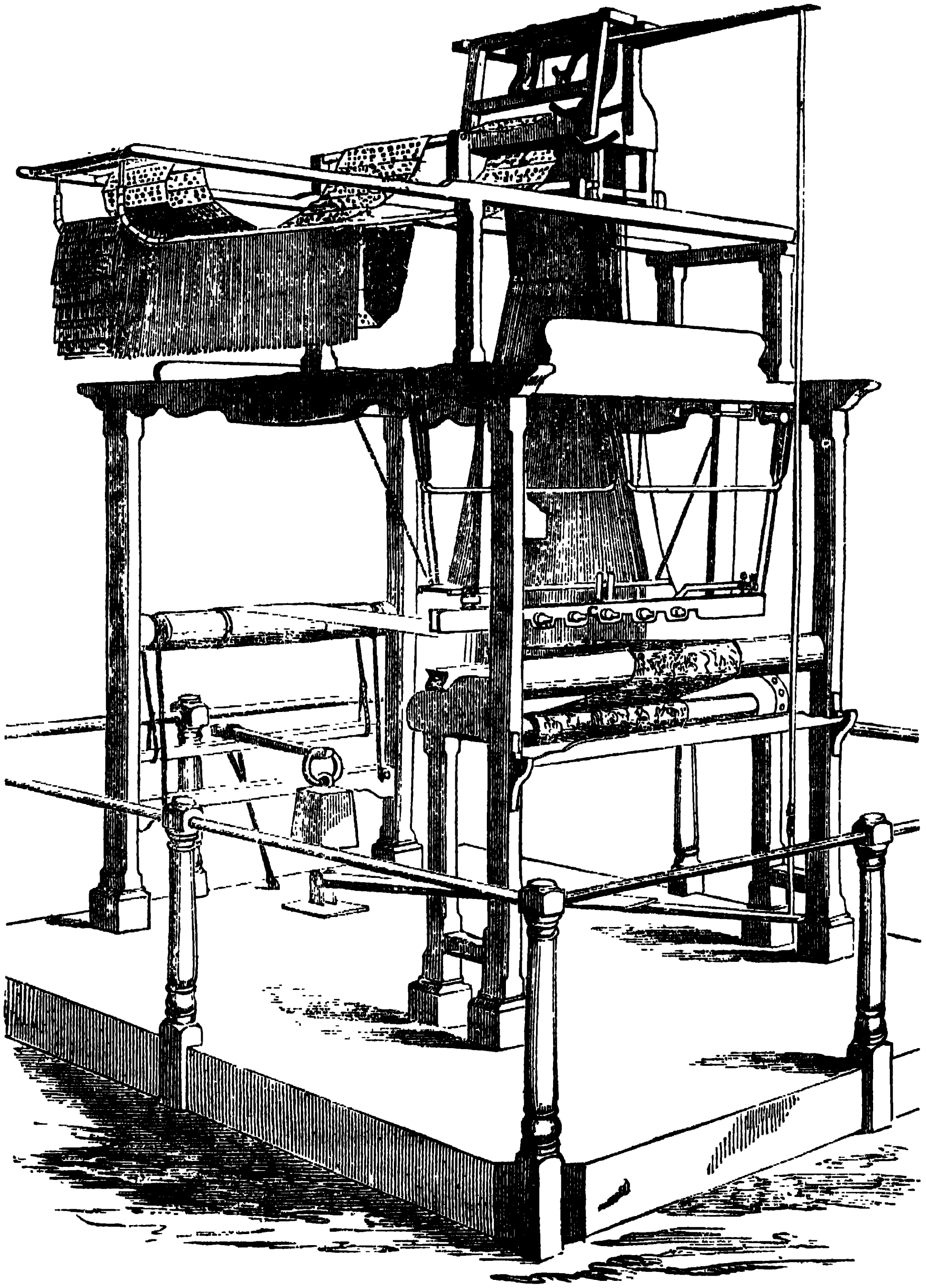
In 1718 the silk-garden scheme was revived, when part of the estate of Sir Thomas More (Chelsea Park) was leased to a company, and 2,000 mulberry-trees were planted. Thoresby, in his Diary, 1728, tells us that he saw "a sample of the satin lately made at Chelsea of English silkworms for the Princess of Wales, which was very rich and beautiful." This scheme also failed; but the Clockhouse, in Lower Chelsea, was long after famous for the sale of mulberries from the trees planted for silk-rearing.

About the year 1789 nurseries of mulberry-trees were planted in several States of the American Union; but though the climate is not unfavourable to the rearing of silkworms, which are found in their natural state in the forests, the high rate of wages was an obstacle to this sort of employment, which is better adapted to the social condition of China, Italy, the South of France, and Malta, where the rate of wages is very low. In 1831 a small quantity of raw silk was exported from the American Union. The production of raw silk in British India is extensive; and labour is not only cheaper than in many parts of Europe, but three crops of silk may be taken in the year, while from countries west of India, including Turkey, only one can be obtained. The Chinese method of rearing silkworms has been introduced in St. Helena, but was soon given up. Some of the silk produced in France is believed to be better than that of any country in the world. The Italian silk is also highly esteemed. In Russia, Peter the Great formed mulberry plantations; and the rearing of silkworms was much encouraged by the Empress Catherine. In Bavaria and other parts of Germany, with the exception of Saxony, the silkworm is successfully reared as a commercial object; also in Sweden, where the silk is said to possess some valuable properties not found in that produced in a warmer latitude. In 1835 an attempt was made on a large scale by a company planting eighty acres in the county of Cork, with 4,000 mulberry-trees, but the design was soon abandoned. In 1839, Mr. Folkin produced at Nottingham some fine cocoons from eggs from Italy. Mr. Whitby, at Newlands, near Lymington, Hants, for many years reared silk with success from eggs of the large Italian sort, of four changes; and twenty yards of rich and brilliant damask manufactured from silk raised at Newlands have been presented to the Queen. The obtaining of a sufficient quantity of food for the worms at the right time has hitherto been the great difficulty of growing silk in England. In 1846 scarves were manufactured in Spitalfields from the produce of between 700 and 800 silkworms kept in an attic room at Truro; in size and weight the worms surpassing those in Italy, the cocoons larger, and the quantity of silk exceeding the Italian average.

British silks have long been equal to those of Lyons; the weavers of Spitalfields, Derby, Cheshire, Lancashire, and other districts in England being equal to French weavers; the deficiency, if any, is rather in the quality of the raw silk than in the manufacture of the article. Reeling the silk is a very material branch, which is never done in England, though silk-reeling is light and delicate work, well suited to women and children. It is generally supposed that the cocoons are injured in the carriage, but this is a fallacy. The worms are first carefully destroyed, and the cocoons are then packed in safety; so that the real difficulty is that of procuring silk carefully reeled from the cocoons.

Raw silk is the silk in its natural state when wound from the cocoon. It varies in fineness according to the number of cocoons reeled off at once to form one thread, the filaments of which are united by their viscid property. In the process of dyeing, the gum is discharged more or less, and the fibres become loose and unfit for weaving; the raw silk is therefore manufactured first into *singles*, *tram*, or *organzine*. By *singles* is signified one of the reeled threads twisted. *Tram* (from the French *trame*, or "shoot"), is formed of two or more threads twisted together, and is used for weaving ribbons for the shoot or weft. *Organzine* is formed of two or more *singles* twisted together in a *contrary* direction from that of its component singles. *Marabout* is silk thrown twice, and is made from the fine white silk from which the gum has not been boiled; that of the French is best. The preparation of the silk is the business of the throwster, a word formed from the word "throw," in the obsolete sense of "to twist, to twine."

In plain silk-weaving the process is much the same as weaving linen or woollen; but the weaver is assisted by a machine for the even distribution of the warp, which frequently consists of 8,000 separate threads in a breadth of twenty inches. The Jacquard loom, invented by a weaver of Lyons, has been the means of facilitating and cheapening the production of fancy or figured silks to an extraordinary extent. Patterns which required the greatest degree of skill and the most painful labour are produced by this machine by weavers of ordinary skill, and with little more labour than that required in weaving plain silks. Persian, satin, gros-de-Naples, ducapes, satin, and Levantine are the names given to plain silks, which differ from one another only in texture, quality, and softness. Satin derives its lustre from the great proportion of the threads of the warp being left visible, and the piece being afterwards passed over heated cylinders. Other varieties of silk goods are produced by mechanical arrangements in the loom, such as using different shuttles with threads of various substances, etc. The pile of velvet is produced by the insertion of short pieces of silk thread, which cover the surface so entirely as to conceal the interlacings of the warp and woof. There are several sorts of goods in which silk is employed with woollen materials, as poplins and bombazines.



THE JACQUARD LOOM.

Ribbons were early wrought with silk, and they formed a branch of the silk manufacture during its progress from Greece to Sicily, and from thence to Italy and Spain; but the ribbon trade seems first to have assumed distinct importance in France. The making of ribbons and small articles in silk long preceded in England that of broad silk. "The best ribbons made in France are those prepared for the English market; the home consumption is chiefly of less costly goods." ("Penny Cyclopædia.") But many ribbons are produced in Coventry which equal in quality their foreign rivals of the same make.

The perseverance of our manufacturers long since enabled them to ship British bandana handkerchiefs for India. In the printing of silk handkerchiefs there has been great improvement; and most of the India handkerchiefs are now printed in England.

On the steam-factory system, the manufacturer gets every preparatory process done; and by steam-power one-half of the weaving process itself—the shooting down—all that is left to the weaver being the picking up and attendance. The profitable application of steam-power to silk-weaving was long considered to be almost impossible, so large a portion of time being consumed in the handling and trimming of the silk, in proportion to the time that the loom is in motion, and a consequent waste of power; but steam has become the chief motive power of the ribbon as of other manufacturing districts. Jacquard steam-looms are employed in making light figured ribbons with great precision and beauty.

The silk culture of France has of late years suffered a severe check in consequence of an epidemic among the worms and the production of unhealthy eggs. This, however, has been overcome to a great extent, and it is hoped that this branch of French industry will soon attain its former prosperity.

OPTICAL INSTRUMENTS.—VII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

THE OPHTHALMOSCOPE.

I HAVE previously stated that where the diagnosis of an eye indicates defects or complications that place its legitimate treatment within the domain of the surgeon rather than that of the spectacle-maker, much may be learnt by the use of the ophthalmoscope; but as its indications must be interpreted by anatomical experience, I shall only describe the optical arrangements of this instrument, and refer all who wish to become acquainted with its use to the excellent practical treatise of Zander, an English translation of which has been edited by Mr. R. B. Carter.

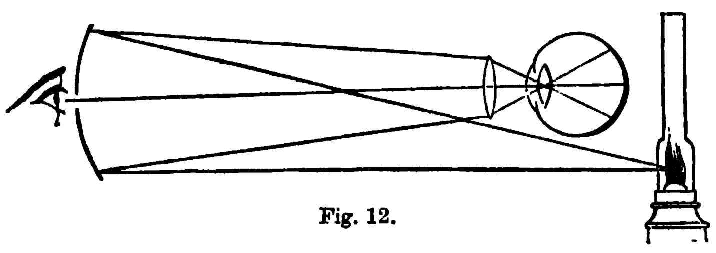


Fig. 12.

Liebreich's Ophthalmoscope.—The object of this instrument is to illuminate the interior of the eyeball, and then be able to observe a magnified image of its various parts.

In its simplest form the ophthalmoscope consists of a concave mirror an inch and a half in diameter, silvered at the back by Liebig's or Petitjean's process, pierced in its centre with a round hole of about $\frac{1}{10}$ inch in diameter, and having a focal length of about 6 inches. Behind the mirror is a support for eye-pieces, which may be convex lenses of 10 or 12 inches focus, or concaves of 6 to 12 inches focus, taken from the "trial case." This is used in conjunction with two "object-glasses," which are convex lenses, one of about 1¼ to 2 inches focus, and the other 2½ to 3 inches focus, of about the same diameter as the mirror. The mirror and object-glass may be packed in an ebonite box not exceeding the size of a small watch, and then constitute the most portable form of the ophthalmoscope. In using this, the patient is placed in a dark room, face to face with the examiner, an argand lamp is placed beside and a little behind the patient's head, with the flame on a level with his eyes. The examiner places his eye close behind the aperture in the mirror, and then while about a foot distant from the patient directs the light of the lamp into the eye under observation. Should the relative refractive power of the eye of the observed and observer require it, suitable eye-pieces may be fitted behind the mirror. By approximating the mirror nearer and nearer, the cornea, lens, vitreous, optic nerve, yellow spot, intra-ocular vessels, etc., may be successively examined, and any pathological symptoms noted. This is termed "*the direct method,*" the natural lenses of the observed eye forming a convex triplet, which gives an erect, virtual, magnified image of the parts seen. By employing one of the object-glasses (held between the finger and thumb of the observer's left hand, about an inch from the patient's eye, with the other fingers resting against the forehead to steady the lens) a larger field of view is attainable, with greater facility for observation. By proper adjustment of the mirror an inverted real image of the parts is seen. This is termed "*the indirect method*" of observation, and it must be observed that the rays of light reflected from the *fundus oculi* strike the object-glass, and form the inverted real image—in normal eyes *at*, in myopic eyes *within*, and in hypermetropic eyes *beyond*, the focal length of the object-glass. Should the eye of the observer be defective, the inverted image will be improved by employing a suitable convex eye-piece. Fig. 12 shows the general arrangement of the ophthalmoscopic apparatus, and some interesting matters relating thereto will be found at page 53 of Vol. VI. of THE POPULAR EDUCATOR, under the head of "Recreative Science."

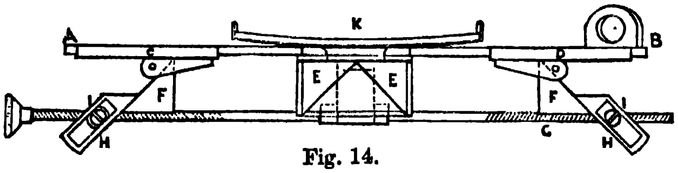


Fig. 14.

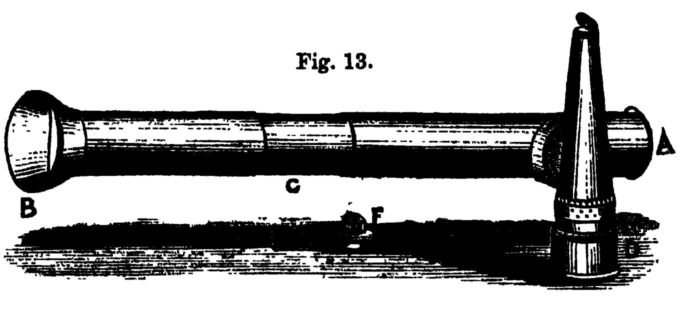


Fig. 13.

Beale's Demonstrating Ophthalmoscope.—The inconvenient necessity for making ophthalmoscopic observations *in a dark room* has been entirely obviated by an arrangement recently devised by Dr. Lionel Beale, F.R.S., Physician to King's College Hospital—shown in Fig. 13. This consists of a telescopic tube C, about one inch diameter, to the upper end of which a small paraffin lamp, furnished with a metal chimney and a bull's-eye lens, is attached by a rotating fitting, to allow of the observing tube being inclined at any convenient angle, while the chimney stands perpendicular. The rays collected by the bull's-eye are projected on a silvered mirror pierced in its centre with a small aperture. The end of the tube B, which slides or adjusts on C, is fitted with a piece of wood shaped to the margin of the orbit of the eye. On this end being applied to the patient's eye, the interior of the eye becomes perfectly illuminated by the light reflected from the mirror, and a magnified image of the *fundus* is obtained by means of an object-glass of 2½ or 3 inches focus, fitted to the lower end of the tube C, and observed through an aperture at A, in front of which an eye-piece may be fitted when desired. An accurate focus is obtained by sliding the tube B on the tube C, the average point of focus being indicated by a mark on the tube C. The object-glass is mounted so that it may swing on a vertical axis, and be inclined so that the reflections from its anterior and posterior surfaces (which would interfere with the distinct image of the retina) may be thrown out of the field of vision, an inclination of less than a quarter of an inch being sufficient. This adjustment also prevents reflections from the lenses of the patient's eye becoming inconvenient. It should be observed that a plano-convex lens, with its plane surface towards the observer, thus mounted, reduces the annoyance from reflection to a minimum. When this apparatus is not in use, the reservoir of the lamp D is unscrewed, and plugged with a screw shown at F. The chimney and burner are turned horizontal with the telescopic body, so as to make the arrangement portable, for packing away in its travelling case.

This ophthalmoscope can be held in the hand, or it may be mounted upon a stem or tripod stand. It can be used in any room in *full day-light* or *when lamps are lighted. This arrangement entirely obviates the necessity of the dark room for ophthalmoscopic observations.* The eyes may be examined when the patient is in the recumbent posture as well as when sitting or standing, and in many cases without using atropine. When an observation is to be made the observer should request the patient to direct the other eye so that he may see distinctly some object on a wall from 8 to 10 feet distant, as a spot in the pattern of the paper, or a red wafer or piece of sealing-wax placed there for the purpose, about one foot higher than the level of the eye of the patient. The patient should be told to look, now a little above or below, to the right or to the left of this mark, until the optic disc, with the vessels, comes well into view; in many instances this will be immediately. The reason for preferring a distant object to a near one (as a ball attached to the end of a bar connected with the ophthalmoscope itself) is, that the *pupil dilates*, while it will contract if a near object be selected; and then by reason of its smallness, a good view of the disc cannot be obtained without the previous use of atropine. This is the most convenient form of ophthalmoscope for clinical demonstration.

Laurence and Heisch's Binocular Ophthalmoscope.—In the use of the ordinary arrangement, the details of the fundus appear to be all in the same plane, so that the indications of abnormal elevations or depressions must be, as it were, translated to the mind of the observer by noting the change of plane, to secure perfect definition of each part while focussing. But if both eyes of the observer are brought into play, then the various parts will be brought into natural or stereoscopic relief, and the observation greatly facilitated. To this end Dr. Girand-Teulon contrived a binocular ophthalmoscope, but did not provide an adjustment for difference of distance between the eyes of different observers; so that the two images could not, with his instrument, always be combined, except by a forced convergence of the eyeballs, which entails fatigue. This serious defect has been remedied by the adjustments provided in the arrangement of Laurence and Heisch. Beyond the greater accuracy of vision obtained by the perception of relief in the object viewed, a greater amount of light, with a more extended field of vision, is also secured. The essential parts of the instrument are shown in Fig. 14.

In using this arrangement the lamp is placed behind and above the head of the patient, in a line central with the observer. The instrument is held horizontally, so that the light from the lamp is reflected into the eye of the patient by means of the perforated mirror K. The image of the fundus is received upon the reflecting surfaces of two rectangular prisms E, E, placed behind the aperture in the mirror, from whence each prism reflects an image to the prism F F, from which each image is reflected into the eyes of the observer, placed close to these "ocular prisms." The ocular prisms F, F can be made to slide on a bar A B, and coincide with the optic axes of the observer's eyes, while simultaneously, by means of a slot and nut, and an endless screw adjustment H I, H I, the prisms are tilted to a suitable inclination for perfect observation from the reflecting surfaces. Convex eye-pieces, 8 and 10 inches, are provided, which can, when desired, be placed in clips in front of the ocular prisms. This arrangement may be used for the "direct" or the "indirect" method of observation.

The method of placing this instrument in adjustment for *each* observer is as follows:—

See that the nuts I, I are in the centre of the slots H, H; if not, bring them there by turning the screws G, G. (If care be not taken on this point, the instrument may be strained in adjusting the slides.) Having carefully measured the distance between the pupils of the observer's eyes, move the slides C and D till the marks on them correspond to that distance on A B. (Thus, if the observer's pupils be 2·4 inches apart, the slides must be set at two divisions from the lines marked 2 inches. Great care must be taken to place them equi-distant from the centre. Now turn the screws G, G, till the nuts I, I again occupy the centre of the slots H, H. Place a light about eighteen inches in front of you, and holding the instrument quite horizontally, look through the prisms F, F. Two images of the light will now be seen. Ascertain that they are of equal brightness, by first shutting one eye, and then the other. If they are not equally distinct, it is a sign that the correct distance between the pupils has not been taken, and the slides must be moved till the images are equally bright: now turn the screws G, G. and the images will approach each other; when they perfectly coalesce, the instrument is adjusted.

There are other modifications of Liebreich's ophthalmoscope, which are designated by the names of the modifyers. At the Cambridge meeting of the British Medical Association Mr. Ernest Hart exhibited a demonstrating ophthalmoscope, somewhat on the plan of Beale's, but it was not by any means as portable or conveniently arranged.

BRICK AND TILE-MAKING.—I.

TERRA-COTTA, BRICKS, AND TILES.

BY GILBERT R. REDGRAVE.

CLAY, which is the result of the disintegration and attrition of the various primary rocks, is widely distributed over the earth's surface. It is found in almost every degree of impurity among the more recent deposits, and in a state of comparative purity in the coal measures and lower oolite—as a soft or friable earth in the former, or consolidated into rocks of considerable hardness and durability in the latter formation. Its colour varies, according to the quantity it contains of lime, iron, or bitumen, from almost pure white, through every shade of red, blue, and brown, to deep black.

The employment of clay by the potter dates from the most remote periods, for not only do we everywhere find the simple earthen vessels which man requires for his domestic wants associated with the earliest traces of civilisation, but we are expressly told in the Bible that with bricks moulded from clay the dwellers on the plains of Shinar began, 4,000 years ago, the famous "tower whose top should reach unto heaven."

It is our intention in the present series of papers to treat of clay as used only for structural purposes, and this we propose to do, not historically, but solely with the view of bringing under the notice of our readers the processes now most commonly practised in different parts of the country for manufacturing from clay the materials known as bricks, tiles, and terra-cotta.

Pure clay, which is, chemically speaking, a hydrous silicate of alumina, contains about 47 parts per cent. of silica, 40 parts of alumina, and 13 parts of water. This is very nearly exactly the composition of the substance known as kaoline, or china-clay; but fire-clay, pipe-clay, and potters' clay, are all comparatively pure silicates, having, however, a much larger proportion of silica than kaoline. The purer clays are, of course, selected for the best descriptions of pottery and terra-cotta; while the earthy clays, or loams, and the clays largely impregnated with iron and lime, which occur chiefly in the more recent formations, are used in the manufacture of bricks, tiles, and the commoner kinds of pottery. Commencing our remarks with terra-cotta, which is derived from two Italian words, *terra*, "earth," or "clay," and *cotta*, signifying "baked," or "burnt," we may state briefly that all the finer and better classes of prepared clay goods really come under this head. The difference between bricks and terra-cotta is an imaginary rather than a real one. Some would have it that terra-cotta is a vitrified brick, or a brick the silica contained in which, owing to its having been burnt at a high temperature, and to its being mixed with certain proportions of alkali or other flux, has been more or less converted into glass, as in the best stoneware. This definition, however, is far from being accurate, as terra-cotta is rarely if ever vitrified, except on the surface; and a better distinction would be to assume that all fine-grained clays which will resist a long-continued firing, and burn so hard as to become incapable of being scratched with the point of a penknife, may be regarded as terra-cottas; while the siliceous, porous clays, which would fuse at a high temperature, and admit easily, when burnt in the ordinary way, of being scratched with the knife, may be classed with the brick-earths.

Terra-cotta is generally made either of pure clay, which burns of a white or pale yellow colour, or from impure clay, which, owing to the presence of oxide of iron, burns to some shade of red. Much of the terra-cotta in England is made from clay found in the coal measures, called fire-clay, which occurs in beds under each seam of coal. The more recent clays of Dorsetshire, from the neighbourhood of Poole, and those from the southern districts of Devonshire, are also frequently used, together with the clay of Northamptonshire, for this purpose. We will glance in the first instance at a manufactory of terra-cotta from fire-clay, which may fairly be regarded as representative of this class of ware.

In almost every coal-field, without exception, large quantities of fire-clay are raised annually, and carried to spoil as a waste product. The utilisation of these spoil-banks probably led those interested in such matters to make experiments with the clay, and they must soon have found how admirably it was suited for all purposes where great strength, durability, and powers of resisting heat were of value. In course of time brick-works and terra-cotta works became necessary adjuncts of many of our great collieries; and in this way, in the neighbourhood of Glasgow, Newcastle, Leeds, Tamworth, and many other colliery districts, large clay-works are now in operation. The fire-clay, as it is dug, is hard and compact, of a greenish-grey colour, sometimes almost black, has a very irregular shiny fracture, and an unctuous greasy feel, with little taste or smell. It is spread out in layers at the mouth of the pit, and picked or sorted into heaps—such pieces as appear brown and mottled being rejected as containing iron, while those which have a dull fracture and feel gritty to the touch are put on one side for drain-pipes, fire-bricks, and the commonest kinds of ware. Only the best bright clay is used for terra-cotta; and it is thought by some that it is improved by being exposed during the winter months to the action of the weather, which causes it to "fall" or split up into fragments, and thus renders the subsequent grinding a simpler and cheaper operation than crushing the hard dry clay. We believe that this latter advantage is all that is gained by the weathering.

To prepare it for use, the clay is crushed to a fine powder under an edge-runner, or by means of Carr's disintegrator, or some simple crushing machine, and with it is ground up a certain proportion of some refractory substance, such as previously burnt pottery, which may form from one-quarter to one-fifth of the entire mass. The degree of fineness to which this grinding is carried varies very considerably in different manufactories and districts. The coarser ground clay seems on the whole to stand the firing the best, and to dry more rapidly than that which has been very carefully pulverised. We may here point out the object of adding to the fire-clay the broken pottery. It is done mainly with the view of counteracting the excessive shrinkage to which all tough, close-grained clays are liable, as it is obvious that clays which have already been once fired have become contracted to the utmost, and therefore the addition of considerable quantities of them to the raw clay tends to partially prevent it from shrinking. Another motive frequently given is, that "grog," as it is termed, opens the pores of the clay—*i.e.*, that in drying it facilitates the expulsion of the water—it also uses up a waste product, saves a little fuel, and, by giving a certain amount of unalterable matter, helps to retain the clay in the form in which it has been moulded, obviating thereby undue contortion under firing. For highly refractory goods, such as fire-lumps and fire-bricks, the materials are usually much more coarsely ground than for terra-cotta.

The ground clay, then, having been, by a sieving or dressing process, separated into various degrees of fineness, the finer portions are passed by an elevator or otherwise moved into a pug-mill. Here the clay-dust receives the proper proportion of water; and it is thought by some that better results are obtained by using hot water and steam than cold water alone. We believe that abroad it is usual to introduce into the water at this stage a small proportion of potash or soda; and we are convinced that our English manufacturers, when using fire-clay, might copy this practice with advantage. In mixing light powdery clay with water, there is frequently great difficulty in effecting a proper and uniform distribution of the moisture. This has been successfully overcome, however, by causing the mixture to take place on a large flat disc; on this the ground clay is gradually damped by numerous fine jets of water, with which it is brought in contact while it is gently spread and turned about by means of revolving arms or scrapers. The wetting takes place on the outer portions of the disc; and by the action of the scrapers the moistened material is slowly conducted into the barrel of a pug-mill, the orifice of which is immediately beneath the centre of the mixing table.

On issuing from the pug-mill, the clay is ready for immediate use; but there is no doubt that by employing rather more water than is now done, and placing the clay for a time in tanks or pits, till the superfluous moisture had evaporated, a mellowed and more plastic substance would be obtained. This, we may add, is a natural inference from the advantages gained from slipping the clays for the preparation of fine bodies, which process we shall refer to when we are treating of tiles. From the pug-mill the clay is conveyed to the moulder or modeller, where it undergoes a further manipulation at the hands of a sturdy labourer, who cuts from it repeatedly with a wire cutter portions as large as he can conveniently lift, and dashes them back with great force on to the parent lump. This operation, called "wedging," or "slapping," renders the clay more homogeneous, and expels any lurking traces of air and unnecessary moisture.

The moulds for terra-cotta are, we believe, for all hand-pressed work, invariably made of plaster of Paris; they are usually about two inches in thickness, and are therefore, for all but very moderate-sized pieces, very cumbrous and weighty affairs. It is unnecessary here to allude to the preparation of the plaster of Paris, as it is not now considered a branch of the terra-cotta manufacturer's business, though formerly it was customary to boil the plaster-stone at the works. This material is, of course, owing to its power of rapidly solidifying on admixture with water, admirably suited for the moulder; and it has, in addition to this setting power, a wonderful amount of porosity, which enables it to suck out the water from the damp clay, and thus permits of its removal from the mould in a shorter space of time than any other quick-setting cement. It is a fact not so universally known as it deserves to be, that the less water used in mixing up or "gauging" the plaster the denser and harder will be the resulting mould; while plaster which has been mixed with a superabundance of water, though it sets apparently almost as rapidly as that with less water, is much more porous and spongy, and consequently has far less wear in it than if it had been gauged stiffer. Plaster is, to a certain extent, soluble in water—about one part of plaster will dissolve in between 400 and 500 parts of cold water—and the long continued action of the wet clay, and the friction in forcing it in and out, speedily wears away the surface of the mould. It seems strange that, with the knowledge we possess of the substances which will harden plaster, such as alum and borax, and with our numerous hard-setting cements, we have not found some better material for mould-making than plaster of Paris, which forms no inconsiderable item in the cost of the manufacture of pottery.

Before going into the question of the moulding of the clay, it will be necessary to revert for a short time to the subject of shrinkage, and to its practical bearings upon the preparation of the models for any work in terra-cotta. The shrinkage has been scientifically explained by assuming that on the expulsion of the water the particles of clay mechanically re-arrange and distribute themselves over the space which it before occupied. Pure fire-clay contracts between the time of going into the mould and issuing thoroughly burnt from the kiln as much as one-eighth of its lineal dimensions; of this shrinkage, about one-half takes place in its green or raw state, at ordinary temperatures, before going into the kiln, and the remaining half during the firing. By the admixture of some definite proportion of previously burned clay, or other unalterable substance, this contraction may be, as we have already seen, considerably reduced; and by this means some makers modify the total shrinkage to one-twelfth lineally. The difficulty of thus artificially reducing the contraction is that workmen are so careless that the proportion of "grog" used is never twice alike, and the scale adopted for the preparation of the models becomes thereby wholly unreliable.

The plan we recommend in using terra-cotta is to send to the manufacturer a model of some plain moulding, and also one of a piece of highly-enriched work, requesting him to produce from moulds made on these models three specimens in terra-cotta of each. On the receipt of these pieces, together with the models originally sent, it becomes possible by measurement and a system of averages to find out the exact amount of shrinkage for which allowance must be made in the ware furnished by this manufacturer. If, for instance, the original model of the plain moulding was 16 inches long, and the average length of the three terra-cotta blocks from it is 14½ inches, we find, by a simple rule-of-three sum, that for a block to be a foot long in terra-cotta it must be made in a mould 13⅛ inches long; or, in other words, that the contraction of the clay is 1⅛ inches in the foot. Having established this so-called "scale of shrinkage," all that is necessary is to provide for all the drawings a rule on which a length of 13⅛ inches is divided into twelve parts, each one of which represents an inch; and by this rule all the details for the terra-cotta manufacturer will have to be prepared. For any building in which large quantities of this material have to be used, not only the drawings, but also the models for the work should be made under the immediate superintendence of the architect; and for this purpose a shed should be erected on the site of the works, where accurate plaster models for each kind of block may be made. By this means numerous difficulties and misunderstandings are avoided, and the ultimate cost of the ware is reduced; as, if the manufacturer has to make his own models, at his own risk, he must put on a certain percentage for uncertainty and trouble in fulfilling the wishes of his employers.

We may suppose now that the models prepared as we have described have been received at the manufactory. The first step is to coat them with some material which will admit of the ready withdrawal of the fresh plaster with which they will have to be encrusted in forming the mould. Nothing could be better for this purpose than clay water, or soft soap and oil; and having brushed them over with one or the other of these preparations, the work of moulding may at once commence.

THE ELECTRIC TELEGRAPH.—X.

By J. M. Wigner, B.A.

BRIGHT'S BELLS—POLARISED MAGNET—CHEMICAL TELEGRAPHS—BAIN'S—BAKEWELL'S COPYING TELEGRAPH—CASELLI'S PAN-TELEGRAPH.

We explained in our last lesson the manner in which an ordinary Morse instrument may often be read by the sound alone, and also the special modification employed in America for this purpose, and known as the "sounder." An acoustic instrument is plainly a great advantage, since, both eyes and hands being free, the message can be easily written down by the receiving clerk.

Attention has therefore been directed to the construction of improved forms of acoustic telegraphs, and Sir Charles Bright has invented an instrument, known after him as "Bright's Bells," which, with various modifications, has been used on several lines. In this two bells are employed, so selected as to produce notes differing by several tones, and thus to be easily distinguishable. A single stroke on the one of these which produces the higher note is taken as the equivalent of a dot in the ordinary Morse alphabet, while a stroke on the other represents the dash. It will thus be seen that only a single sound is required for each sign, instead of two, as is the case in the "sounder." The signs are for this reason much more simple and distinct.

In a circuit where there are two line-wires, an acoustic instrument of a very simple construction may be used. An electro-magnet may be connected with each line-wire, and the hammers which strike the two bells may then be fastened to the keepers of the magnets. A yet simpler plan is to fix the two bells side by side, just space enough being left between them for one hammer to play on both. The keeper of the magnets is then fixed to the rod which supports the hammer, and the magnets are placed one on each side of this rod so as to face one another. As soon as either magnet is excited by the current passing round it, the keeper will be drawn to it, and the bell on that side will be struck. Two small spiral springs keep the hammer in a central position when no current is passing.

The need of two line-wires is, however, a great drawback in this, since it entails much extra expense both for repairs and maintenance. Bright's instrument was accordingly so contrived as to require but one. This was accomplished by means of a "polarised magnet," the principle of which must be carefully understood, as it is often introduced in other pieces of electrical apparatus. In an ordinary electro-magnet the core consists of a piece of soft iron, and is quite devoid of magnetism, except when the current is circulating round it. In the polarised magnet, however, the cores, instead of being fixed to a piece of plain iron, are placed on one end of a permanent magnet, *n s* (Figs. 43 and 44). In this manner a permanent north polarity is imparted to the poles of each core. The keeper *a b* vibrates on a pivot at *a*, which is in communication with the other end of the magnet, and acquires south polarity. It will thus be seen that the keeper has opposite polarity to the poles between which it plays, and is equally attracted by each; it remains therefore at rest midway between them. If now a positive current be transmitted along the line-wire, the slight polarity imparted to the cores by the permanent magnet will be quite overcome, *d* will then become positive, and *c* negative. The keeper will thereupon be attracted by *d*, and at the same time repelled by *c*, so that it will at once move towards the former. If a negative current be sent, the poles will be reversed, and the keeper will be attracted by *c* and repelled by *d*, and accordingly will move in the reverse direction.

The application of this principle to some of the alphabetical telegraphs will be considered in a subsequent paper. The manner in which it is employed in the acoustic telegraph will easily be understood. All that is required is to fix a hammer or tongue to the end of *a b*, and place the bells on each side of this, so that a positive current will cause it to strike one bell, and a negative the other; or we may have an additional magnet to each bell, and call these into play by means of contact-springs placed at each side of *a b*. The two bells may then be a little way apart.

The commutator employed with the single-needle instrument may be employed to transmit the messages to this instrument, since it is so constructed that positive or negative currents at pleasure may be transmitted by it according to the direction in which we incline the handle.

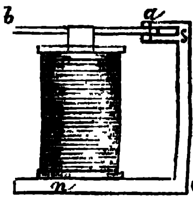


Fig. 43.

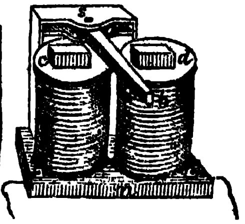


Fig. 44.

We will now turn our attention to those forms of telegraph instruments in which the property possessed by the electric current of decomposing various chemical substances is turned to account.

As the student is already aware, very many compounds may be decomposed or separated into their component parts by means of the electric current; some even which resist almost all other agents may in this way be torn asunder. Now if we can choose any substances which will by their decomposition leave a stain on a strip of paper, it is clear we may by means of these transmit intelligible signs along an insulated wire.

A simple experiment will illustrate this principle. Take a sheet of white blotting-paper, and having wetted it well with a solution of iodide of potassium, lay it on a metal plate—as, *e.g.*, a sheet of tin—connected with one pole of a galvanic battery. Now move the other battery wire about over the surface of the moist paper, and it will be found that a distinct brown mark will be produced wherever the wire has touched. The reason of this is that the iodide of potassium has been decomposed by the electric current, and the iodine which existed in it in a state of combination has been set free and stained the paper. The marks produced in this way are, however, fugitive, since as the paper dries the iodine evaporates, and soon disappears. There are, however, several other solutions which produce permanent marks. That most commonly employed is a solution of ferro-cyanide of potassium and nitrate of ammonia. The paper, which must not be glazed, is cut into strips, and after being wetted with this, is made to pass under a steel point, being carried onwards by rollers as in the Morse instrument. The current then passes through the steel point, and whenever it so passes a blue stain is produced on the paper, the iron of the style or point being slowly dissolved, and combining with the salt of potassium under the influence of the electric current.

In other cases the paper is prepared with starch and iodide of potassium, and in this way too a very clear blue mark is produced. Now we must see in what way this power is made use of in recording a message.

The simplest form of chemical telegraph is that introduced by Bain, and the action of the receiving apparatus will be easily understood by Fig. 45. The line-wire L is connected with the iron style S, which presses against the metallic roller R. This roller is in communication with the earth-plate E.

The strip of prepared paper is drawn onwards towards B by means of the rollers C C, and is thus made to pass steadily along between the point S and the roller R. The message is transmitted by the ordinary key, or by means of a relay, and is thus chemically printed on the strip instead of being embossed or inked.

The receiving apparatus is thus simplified, but there is much more trouble required in preparing the paper, so that on the whole little is gained by the adoption of this plan. This recording apparatus was first introduced by Bain for use with his system of automatic transmission referred to in our last

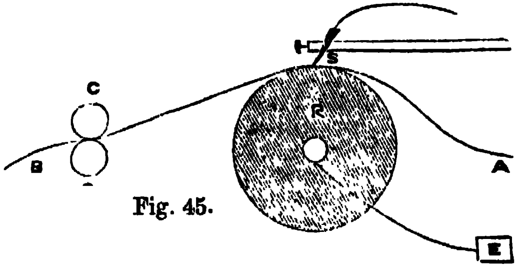


Fig. 45.

paper, and it certainly possesses the advantage of great simplicity of construction in the apparatus. In his original arrangement a disc of prepared paper was employed in place of a strip, and the style was so arranged that it gradually travelled from the centre to the circumference as the disc rotated. Thus the message was traced in a spiral line commencing at the centre, and gradually extending to the circumference.

There are two very remarkable forms of chemical telegraph which we must now explain. In all instruments hitherto described the message has been transmitted in cipher, that is, by means of some arbitrary signs only intelligible to the initiated. In the instruments we are now speaking of the message is received in ordinary written characters, and even the handwriting of the sender is reproduced. It is, in fact, possible to go even further than this, and to transmit a drawing or a portrait by means of these ingenious arrangements.

The operation of these instruments may very easily be understood. In the former of them, which is known after its inventor as Bakewell's Copying Telegraph, two cylinders of the same dimensions are employed, one being placed at each station; these are made to revolve at exactly the same rate. A considerable difficulty was at first experienced in attaining this, but by means of an electro-magnetic regulator Bakewell succeeded in overcoming it. These cylinders are put in electrical communication with the earth at their own stations, and a metallic pointer is placed at one side of each cylinder. This pointer is moved slowly along by means of a long screw, so that for each revolution the cylinder makes the pointer advances about one-twentieth of an inch. The pointers in the two instruments are put in electrical communication with one another by means of the line-wire, the battery being interposed in the circuit.

A sheet of paper prepared in the manner already described is now placed round the cylinder of the receiving apparatus, and it is clear that if a continuous current is allowed to pass a spiral line will be traced from one end of the cylinder to the other, the different lines very nearly touching. When the paper is taken off from the cylinder and unrolled, it will be found to be ruled across with close parallel lines. Any interruption in the current will, of course, cause a break in these lines, and leave a white space; and by duly arranging these spaces, letters or any required marks may be produced. Now a very simple plan was devised by Bakewell for thus interrupting the current so as to produce the required letters. The message to be sent is written with a non-conducting varnish on a sheet of silvered paper or tinfoil the same size as the receiving sheet of paper. When the varnish is dry, this sheet is placed in the cylinder of the transmitting apparatus. The pointer of each instrument is then brought to the end of the cylinder, and both are started. The current passes through the tinfoil, and the pointer which rests on it, then along the line-wire to the distant station, and there it commences to trace its spiral line. As soon, however, as a line written in the varnish comes under the pointer, the current is momentarily interrupted, and a corresponding blank is left in the paper at the other end. In this way every line of the message is faithfully reproduced, and the message appears at the receiving end distinctly written in white letters on a blue ruled ground. Fig. 46 represents the words "Bakewell's" as received by an instrument of this kind.

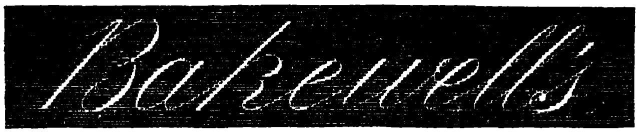


Fig. 46.

If desirable, a relay may be introduced into the circuit so arranged as to reverse the writing, and trace it in blue letters on a white ground. The connections in the relay must in this case be specially arranged, so that when the line-current is passing, the local one is interrupted, and *vice versâ*. There is, however, little need for this alteration, as the message received in the ordinary plan is quite legible. Considerable speed can be attained by this instrument, which is certainly a very remarkable one, but the difficulty of ensuring the synchronous movements of the barrels is a great drawback, and it has not been employed except for experimental purposes, and to illustrate what can be effected by means of the telegraph.

Another instrument of this class was invented by the Abbé Caselli, and was called by him the Pan-telegraph, on account of its power of transmitting in any language, or even, if needs be, in short-hand.

The annexed figure (Fig. 47) shows its construction, and it will at once be apparent that it acts in a very similar way to Bakewell's instrument just described. In place of the cylinders there used, there are here two curved tables fixed to the stand, and on one of these the message is written. The pen, which is mounted so as to travel in an arc, moves from side to side of these, and advances a short distance at each motion. Its movements are controlled by means of a rod connected to the pendulum.

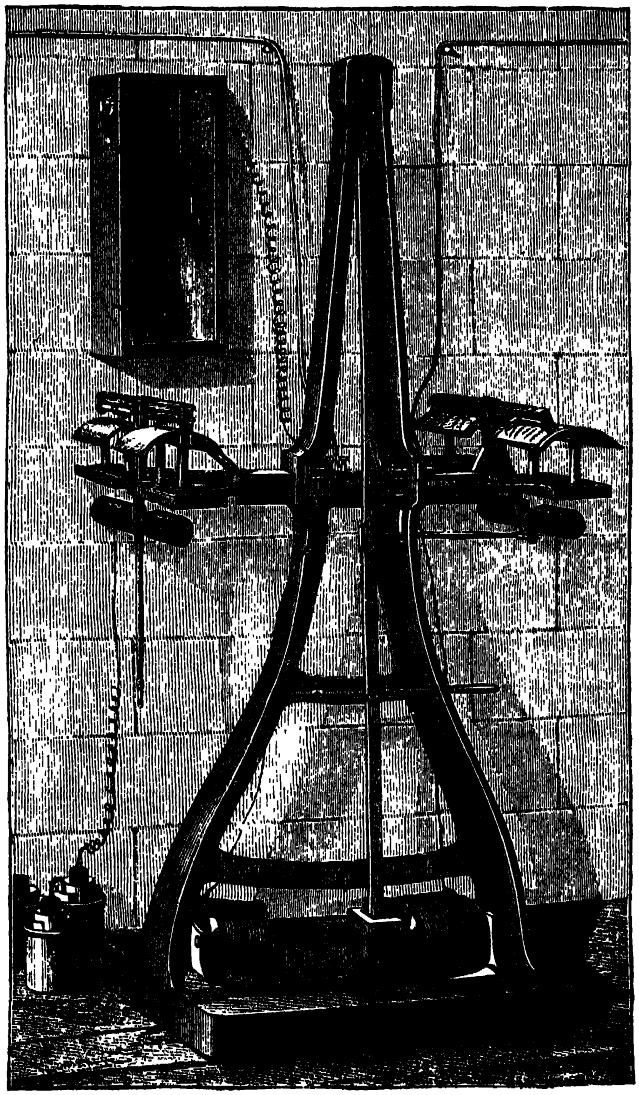


Fig. 47.—CASELLI'S PAN-TELEGRAPH.

The pendulums at each station are similar in length and weight, and their movements are controlled by the electro-magnets seen at the base, so as further to ensure absolute uniformity of speed. Two tables will be seen at each side of the instrument—those to the left are for transmitting the messages, those to the right for receiving them. The reason of there being two tables is that one is used as the pendulum oscillates from left to right, the other as it returns. Two messages are thus sent simultaneously. Either set may be called into action by connecting the loose rod under them to the centre of the pendulum. In the figure the receiving side is at work, the other rod being disconnected. The alarum is placed above the transmitting apparatus, and the rest of the details of this ingenious form of the electric telegraph may easily be understood from the figure itself.

CIVIL ENGINEERING.—VIII.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

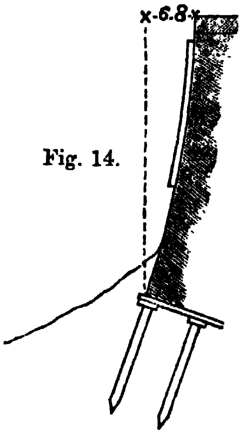
DOCKS.

THERE are a variety of important engineering operations which require to be carried on either beneath or contiguous to water. Special plans of action are required for such operations, and we propose to group the whole together under the general title of *marine* engineering. The subject of this paper stands foremost amongst this class of operations, and to no country in the world are they of such importance as to Great Britain; not only on account of the nature and extent of its coasts, but also on account of its gigantic commercial navy. Wherever its fleets of vessels congregate, either for loading or discharging, there of necessity will our most extensive docks be found.

Docks are of two kinds, *wet* and *dry*. In deciding upon the formation of a dock, the nature of the soil must engage the most careful and particular attention of the engineer—not, it may be, with the idea of changing the locality if the soil be unsuitable, but in order to be prepared for every difficulty which may arise in respect of the soil. The area of the proposed dock is a material element in considering the cost, and whilst upon the one hand it is useless to incur unnecessary expense in this respect, it is equally important, upon the other, to prepare for what may arise in consequence of a probable increase in the trade of the port.

The more important features in the construction of a dock are—(1) the *walls*, (2) the *gates*, and (3) the *approaches*. The height of the walls—that is, the depth of the dock—must depend entirely upon the draught of the vessels which can enter at the highest spring-tide; in other words, it must assimilate itself to the natural depth of water *outside* the artificial entrance, so that any vessel capable of approaching the entrance from without, under any circumstances of tide, can be sure of passing over the sill of the gates, and of floating when inside the dock.

Fig. 14.



The walls of docks require the utmost care in their construction. The soil must undergo a very careful examination by excavation and trial borings, and the foundations be laid at sufficient depths—not less than six or seven feet—below the soil, so as to prevent the possibility of any disturbance of it by the movement of the water, the footings being protected by rows of piles and planking. In some situations it may be necessary to provide for the proper escape of land water, otherwise there is the risk of either its washing away the soil and exposing the foundations, or of its thrusting the entire wall out of its normal position. The best method of doing this is to lead the water by a formed channel, dredged out at a sufficient distance from the wall. The outer and more exposed walls should have considerable slope, which should be increased according to the extent of the exposure; this especially applies to walls exposed to the sea. When dock walls are exposed upon one side to tidal waters with only a small amount of soil intervening, it is necessary that the back face of the wall should be puddled with clay, since the pressure of the enclosed water at low tide has been sometimes known to force itself through the wall and bank.

It seldom occurs that the soil upon which a retaining wall has to be built is sufficiently firm to permit of piles being dispensed with. The whole of the foundations of the Humber Dock wall are piled, the piles being 9 inches square under the main wall, and 8 inches square under the counter-forts, which are 3 feet 9 inches wide. Sleepers of half-timber are bolted down upon the heads of the bearing piles, and the whole covered with four-inch planking. These walls have a perpendicular height of 32 feet, the top receding 6 feet 8 inches from the vertical line. This recession is shown in Fig. 14.

The walls are 10 feet thick at the bottom, and 4 feet 6 inches at the top, and are protected by oak fenders 12 inches square.

In all cases of walls constructed in the sea or in deep rivers, the foundations require the greatest care. In constructing the bridge at Neuilly, Perronet laid over the heads of the piles a of whole timber, and filled it up level with rubble; another series of timbers of the same scantling was laid in a transverse direction, and again brought level by another filling-up of rubble, and the wall built upon it. Similar precautions were adopted for the walls of the docks at Rochelle, which were faced with freestone and backed in with brick, whilst a row of sheet-piling was driven along the whole length of the footing, to prevent the water from acting upon the foundation. There are various methods of attaching the upright fenders to the walls of docks; one very secure plan is to attach them by spikes and angle-irons to T-irons set in the solid masonry.

Instances occur, as at Brunswick Wharf, Blackwall, in which the wall facing the water is constructed wholly of iron. The mode of procedure was as follows:—A trench six feet in depth was dug along the intended line, and timber piles driven therein. The iron piles may be in one or more lengths. If the latter, as was the case at Blackwall, they are fastened together by a socket-joint and screw-bolt. They are usually driven at intervals of about seven feet, and the intermediate spaces filled in with sheeting-piles, which are secured at the top by two bolts to the top wall of the wood-work at the back. The iron plates which fill up the spaces over the sheet-piles were bolted to the main piles and to each other, and the joints stopped with iron cement. At Brunswick Wharf the work is backed by a wall of concrete, and has a granite coping. Upwards of 900 tons of iron were employed in the construction of this wharf, which is 720 feet long.

The gates of docks are in principle the same as those already described in connection with canals, but being as a rule very much larger, they differ in points of detail. They are not unfrequently constructed of iron. In all large gates it is usual to rest the foot of the gate upon a curved traverse plate of iron, by a wheel running on centres fixed to the gate itself, the iron traverse being bedded level into the stone apron.

The balance lever is also dispensed with, and the gates opened and shut by chains running through holes cut in the masonry of the side walls, and passing over friction rollers up to a windlass. The chain may be endless, care being taken to obtain sufficient grip on it, by passing it a number of times round the barrel of the windlass. A fine pair of iron gates are to be seen at the wet dock at Montrose. The entrance to the dock has a width of 55 feet in the clear, the centre of the heel-post being recessed 12 inches within the face of the wall; thus each gate is 28 feet 6 inches wide, and 22 feet 6 inches high. When closed, the line of shutting is 10 feet from the straight line which joins the centres of the heel-posts. These latter are 21 inches in diameter, and in section a little more than a semicircle; they were turned in a lathe after casting. Their thickness is 1¼ inch, and they are made to fit into a cast-iron socket, and work on an iron gudgeon 10 inches in diameter, cast on a plate 4 feet 6 inches long, 21 inches wide, and 2 inches thick. This plate is dovetailed and riveted firmly into the stone, and keyed so as to press the curved side of the heel-post into the quoin. The quoins are cut to the same curve as the heel-posts and are polished, and the contact between the stone and metal surfaces is so close, that scarcely any water is able to pass between. The mitre-posts are 18 inches broad, and 1½ inch thick. They are cast with holes to receive the iron bars, which are eleven in number, 2 inches thick, 16 inches broad at the ends, and 18 inches in the middle. Across their ends are 2-inch plates with 4½-inch screw-bolts, two bolts to each bar, which pass through the heel and mitre posts. The sills against which the gates close are of iron, cast in four pieces 8 inches deep. The bottom rail of the gates is of oak, fixed to the lowest iron rail by 1¼-inch bolts, and bedded to it by a layer of felt. The oak rail is 12 inches thick, 17 inches broad at the ends, and 19 inches in the middle. The gates have a double lining of boiler-plate, the plates overlapping each other 2½ inches. They are ⅜-inch thick for the first 6 feet from the bottom, and $\frac{5}{16}$-inch thick above. The collars supporting the heel-posts are of wrought iron, 4 inches deep and 2 inches thick, keyed through the anchors; these are of cast iron 3½ inches square, dovetailed into the quoins and run with lead.

The curved traverse plates are 10 inches broad and 4 inches thick, sunk into the stone and bolted, and bedded with felt and white lead. The rollers upon which the gates rest are of cast iron, 18 inches in diameter and 5 inches thick, running upon steel axles. The roller-boxes are of cast iron 1¼ inch thick, and fastened by screw-bolts through the sides of the lowest rail. The sluices are 3 feet by 2 feet, and the sluice-valves are 1¼ inch thick. The rods for raising and lowering the valves are 2 inches diameter, terminating at top in a square-threaded screw with brass nut, worked by a wheel and pinion and crank handle. The chains for opening and closing the gates are ⅞-inch, proofed to a strain of 22,000 lb. The entire weight of each gate is about 53 tons, and when closed and the water away from the concave side, they conjointly support a water-pressure of about 384 tons.

The entrances to docks are sometimes closed by means of pontoons, which are large hollow vessels fitted with a kind of keel or projection round the sides and bottom. This keel corresponds with and fits into a recess cut in the stone-work of the entrance. The water being withdrawn from the pontoon by pumps attached to it, it can be floated over the recess, and if then gradually filled with water, it will settle down into it and effectually close the entrance. Pontoons are constructed either of timber, copper, or iron. There is only one objection to their use, which is the necessity for their being floated entirely away when a vessel requires to pass the entrance; in other respects they have an advantage over gates, both in simplicity of construction, and freedom from the wear to which large gates are subjected. They may therefore be employed with advantage in closing dry docks, which do not require to be frequently opened and shut.

It would be useless to enumerate all the very excellent docks which this country possesses, but some of the more important deserve a short notice, possessing as they do points both of interest and instruction. First in importance are the many extensive docks and basins situated upon the banks of the Thames, and communicating with the river.

The London Docks, completed in 1805, were amongst the first opened. These splendid works were executed under the supervision of Mr. Rennie, and occupied five years in construction. They have two entrances, one at Wapping, and another higher up the river at Hermitage. The entire area within the boundary walls is about 71 acres, of which 27 acres are water. A vast amount of water percolated into the excavations, requiring the constant use of an engine of 20 horse-power to keep it under.

The East India Docks, the works of which were executed under the direction of Mr. Rennie, consist of two docks, the export and import, and a basin, having an area respectively of 10, 19, and 3 acres, with a depth of water of about 26 feet.

The West India Docks consist of two docks and two basins. The docks lie parallel with each other, and are 890 yards long, the larger being 500 feet broad, and the smaller 400 feet broad, and contain respectively 30 and 25 acres. The basins form connections between the river Thames and the extremities of the docks, and are respectively 2 and 6 acres in extent. The water in the basins is nearly the same level with that in the docks, and the length of time the water remains in them before passing into the docks, enables the sediment to be deposited in them.

The St. Katherine's Docks were constructed under the direction of Mr. Telford, in 1828. Although not so extensive as some of the others upon the Thames, they are yet very complete in their arrangements. The lock by which they communicate with the river is 45 feet wide, and 180 feet long. There is a depth of water over the sills of 28 feet at spring-tides, and of 10 feet at low springs. The water-area of the docks, basin, and entrance is 11 acres. The water is readily maintained at the same level in the docks and basin, by means of two steam-pumps of 80 horse-power each, which draw their supply from the river. The soil upon which the walls of these docks are built is a hard gravel, which being pervious to water, it was necessary to line the whole of the bottoms of the docks, and the foundations of the walls and counter-forts with impervious cement, and to puddle the backs of the walls with clay. The concrete upon which the walls stand is composed of eight parts of coarse sand and one of blue lias lime, and was laid on 12 inches in thickness. A sill of wood was laid under the front edge of the wall, and protected by a row of sheeting-piles 14 feet long and 9 inches thick, driven close and having their joints caulked for 3 feet in depth. The entrance lock is built of grey stock bricks, laid in mortar made with lias lime, and the platforms, copings, and hollow quoins of Bramley Fall stone laid in cement.

Whenever practicable, it is advisable to keep a harbour free from mud by sluicing. Hartlepool affords a good example of this system. The channel for conveying the scouring water is a tunnel 15 feet wide and 4 feet high, between the springing of the top arch and invert. The thickness of the side walls is 5½ feet, protected by external buttresses 3½ feet thick, and 4 feet projection. The tunnel throughout is floored with 3-inch plank. The sluice-gates or paddles are of cast iron, and work in cast-iron frames.

The retaining walls of the Hartlepool Docks have a curved face, being 12 feet wide at the base, and 6 feet at the top. The curve represents an arc of a circle, having a radius of 80 feet.

The most magnificent and extended range of docks in the world is situated at Liverpool, upon the north bank of the Mersey. Upwards of thirteen spacious docks are collected at this port, exclusive of basins; of which eight are connected together by locks, whilst another group of four lie to the east of the others, these also being connected together by locks. There are altogether nine separate entrances from the river. The first dock was constructed here in the reign of Queen Anne, and is called the Old Dock; and the others have followed in rapid succession, so great has been the increase in the shipping of this port, and the consequent demand for dock accommodation. The Old Dock measures 198 yards by 85 yards, and is one of the smallest of the whole. Another, the West India Dock, measures 867 yards by 170 yards, and is 29 feet deep; this alone will hold nearly 300 ships. The several docks are connected by scouring tunnels and sluice-gates. The operation of sluicing is exceedingly effective and simple. A dock about to be cleaned is left dry at low water by closing the gates, and the various sluice-gates being opened, a number of men with shovels enter the dock, and throw the accumulated mud into the channels formed by the sluices, which carry it out into the river. The spring-tides rise to a height of 33 feet at Liverpool, and at this period there is a depth of 89 feet in the channel of the Mersey opposite the docks. The quays alongside the docks are very extensive and well constructed, and to facilitate the shipment and unshipment of goods, a continuous line of rails is carried along the north side of the docks from east to west, and connected with the great railway system of the country by branch lines. A complete system of telegraphic communication also exists between the various docks and the Custom House.

Very extensive docks exist at Bristol. A company was formed in 1804 for constructing docks at this port. They cover 82 acres of ground, and extend along the banks of the river Avon for 2½ miles. The engineer, Jessop, subsequently diverted the river for a length of two miles, and cut a canal to carry off the water. The channel thus drained was converted into a splendid floating dock of 70 acres area, having an entrance basin opening by double locks into the Avon below, and by a single lock into the old channel above.

SEATS OF INDUSTRY.—XIII.

BRADFORD.

BY WILLIAM WATT WEBSTER.

About eight and a half miles to the west of Leeds, and thirty-four miles to the south-west of the city of York, stands Bradford, the chief centre of the worsted manufactures of England, and the principal mart for the long wools used in worsted fabrics. The site on which the town is built is exceedingly healthy, as is proved by the low annual rate of mortality; and the surrounding district is very fertile, and yields an abundant supply of coal and iron. From the circumstance of Roman coins having been found in the refuse of an ancient bloomary in the neighbourhood, it is believed that the iron mines were worked by the Romans during their occupation of the island. But before the Norman conquest nothing is known respecting Bradford except that it formed part of the parish of Dewsbury, and its earlier history is entirely associated with the castle of the Laceys, Lords of Pontefract, which was erected there shortly after that event.

The loosely spun woollen yarn called worsted received its name from the little town of Worsted in Norfolk, where it was manufactured as early as, and probably before, the time of Edward II. At what date this industry was first introduced into Bradford cannot be ascertained. In the Act 33 Henry VIII. c. 16, worsted yarn is described as "the private commodity of the city of Norwich;" while the Act 34 and 35 c. 10 of the same monarch, after declaring "that the city of York afore this time had been upholden principally by making and weaving of coverlets, and the poor thereof daily set on work in spinning, carding, dyeing, weaving, etc.," and that the manufacture having spread into other parts was "thereby debased and discredited," enacted that henceforth "none shall make coverlets but the inhabitants of the city of York." At this time Bradford almost rivalled Leeds as a woollen cloth-making centre, but both towns were surpassed by Wakefield, and worsted-making was one of the special occupations of the inhabitants of Bradford, although Norwich was then the chief centre of the manufacture. Owing to the settlement of Flemish artisans in Norwich, in the reign of Queen Elizabeth, and the improvements they introduced, the worsted trade of Bradford declined during the seventeenth century, but throughout the greater part of the eighteenth century it was gradually returning, in consequence, it is said, of the extravagant wages demanded by the workmen of Norwich, which drove the masters to the cheaper labour market of Yorkshire. However, in 1800 the population of Bradford only numbered 6,400.

The only events of any great political importance connected with Bradford took place during the Civil Wars, when the inhabitants espoused the cause of the Parliament, and twice defeated the Royalists, but were themselves afterwards defeated by a force under the command of the Earl of Newcastle. With these exceptions the history of the town is wholly industrial, and the period of greatest interest is the last eighty years. Bradford has increased and prospered as machinery has been more and more applied to the branches of manufacture cultivated in the district; but it was with the greatest difficulty that this advance was made, owing, in the first instance, to the opposition of the townspeople generally, including the manufacturers, and, in later instances, to the opposition of the operatives. In 1793, a Bradford manufacturer named Buckley wished to erect a mill to be driven by steam-power, but desisted in consequence of being threatened by his neighbours with a prosecution for nuisance. In the following year the first spinning machinery of Crompton's make was started by James Garnett, the founder of one of the largest manufactories in the kingdom, and within ten years after several thousands of spinning machines were in operation in the town. The extension of machinery placed the workpeople at a disadvantage for a time, and, under the mistaken impression that their condition would be permanently injured, they resolved on the destruction of the novel inventions. A great riot took place in 1812, which was quelled by the military and the police, and seventeen "Luddites," as the rioters were called, were condemned to death and executed. But the machinery went on increasing, notwithstanding the antipathy of the workers, and by 1815 there were ten mills in Bradford, with an aggregate of 256 horse-power. In 1825 the number of mills was twenty-six, and the horse-power had risen to 706. The workmen, however, were not yet reconciled to the change in the system of manufacture, and in this year 20,000 persons engaged in a strike for increased wages, which lasted six months, and caused wide-spread suffering. In 1826 another organised attempt was made to check the spread of the obnoxious machinery by force. A riot, specially directed against the worsted power-looms that had been recently introduced, broke forth, in the course of which two of the rioters were shot dead, and several severely wounded, by the defenders of the factories. After this occurrence the opposition to machinery seems to have gradually subsided, and in 1835 there were in Bradford 73 mills, with a steam-power equal to 1,647 horse. Fifteen years ago the worsted factories in Great Britain numbered 525, and gave employment to 87,794 persons, and no fewer than 186 of those factories, employing 30,517 persons, were situated in the town and neighbourhood of Bradford. Since then very marked progress has been made. Within the past few years many merchants from Leeds and Manchester have established their head-quarters at Bradford, and the town has been greatly improved in many respects and considerably extended.

The population of the town and parliamentary borough of Bradford has steadily increased throughout the present century. In 1821 Bradford contained 13,064 inhabitants; in 1831, 23,233; in 1841, 34,560; and in 1861, 48,646. The townships of Manningham, Bowling, and Horton, and the villages of Great and Little Horton, are included within the Parliamentary boundary, which in 1841 comprised 66,508 inhabitants, and in 1861, 106,218. The Reform Bill of 1832 gave two representatives to Bradford, and the date of incorporation is 1847. The town is built of free-stone, and partly on the side of a steep hill, some of the streets overlooking the houses in the lower parts. The streets in the older quarters are narrow, but those more recently constructed are broad, well-paved thoroughfares, and constitute the larger portion of the town. Bradford enjoys facilities of communication with the ports on the east and west coasts by means of the Leeds and Liverpool Canal, a branch of which has been brought into the very centre of the town.

Besides worsted stuffs, mixed worsted, alpaca, and mohair goods are manufactured on an extensive scale at Bradford. Cotton and silk fabrics also form important branches of industry in the town, and the spinning of worsted yarn, to be woven in the power-loom factories, and for export, employs a large number of persons. Broad and narrow cloths, wool-cards, and horn combs are also made in large quantities in the town and neighbourhood, and the dye-works are very extensive. The Low-moor Iron Works, three miles south-east from Bradford, and the Bowling Iron Works, one mile to the eastward of the town, are large establishments, celebrated for the quality of the iron they produce; but this manufacture, although considerable, is not so extensive as might have been expected. But the most famous and the largest manufacturing concern in the vicinity of Bradford is the Saltaire Alpaca and Mohair Works, situated on the Aire, at a distance of about three miles, and which form, with the residences of the workmen and others employed in the works, a flourishing town which is fast rising into importance.

About the year 1834, Mr. (now Sir) Titus Salt, a young farmer, and the son of a Leeds wool-stapler, settled in Bradford as a spinner, and shortly after began to make experiments with a parcel of alpaca wool that had been sent to this country from Peru many years previous to that date, and had been laid aside in a Liverpool warehouse as useless, unworkable material. In 1835 Mr. Salt bought 300 bags of the "South American stuff," at eightpence per pound, and set to work to manufacture it. By 1853 upwards of 2,000,000 pounds of alpaca wool, the greater part consigned to Mr. Salt, had been imported into England, and in that year he built the Saltaire Mills and the adjoining town, which is capable of accommodating 5,000 persons. Upwards of 4,000 workpeople are employed in the Saltaire establishment, which covers six acres of ground. The town itself, with its various institutions for the health, recreation, and instruction of the inhabitants, may be regarded as one of the best models of a well-regulated industrial community that we possess.

Bradford contains a free grammar school, founded in the reign of Edward VI., and chartered and partly endowed by Charles II., which was rebuilt in 1830. This school is open to all boys belonging to the parish, who may become candidates for an exhibition in Queen's College, Oxford. On the outskirts of Bradford is Airedale College, an institution for the preparation of young men for the Independent ministry, and at Little Horton the Baptists have a similar academy. At Woodhouse Grove the Wesleyan Methodists have a school for ministers' sons, and at Fulneck, five miles to the east of Bradford, there is a Moravian settlement. Among the public buildings the most prominent and noteworthy are the Piece Hall, built in 1773, and used for the exhibition and sale of alpaca and other stuffs; the Court House, built in 1834; and St. George's Hall, an edifice in the Corinthian order of architecture, erected in 1853 at a cost of £28,000, and capable of accommodating 3,350 persons. Bradford has also a fine public park. There are three important annual fairs held at Bradford, and the wool sales are attended by buyers from the most distant parts of the country. Every seventh year a festival in honour of Bishop Blaise, the reputed inventor of wool-combing, is celebrated in the town with great gaiety.

WEAPONS OF WAR.—X.

BY AN OFFICER OF THE ROYAL ARTILLERY.

ARTILLERY CARRIAGES.

HAVING already given an account of the various natures of guns which the present state of artillery science recognises as best adapted for offensive and defensive purposes, we proceed to consider the mechanical appliances external to the gun itself, which are designed to complete its efficiency as a tool in the soldier's hand. All such appliances are embodied in the gun carriage, its furniture and accompaniments. These in the field artillery would include the limber, ammunition wagon, and other vehicles; and, in the garrison or naval artillery, the platform or slide on which the carriage is worked.

Too much importance cannot be attached to the object of perfecting the carriage with its equipment. Indeed, it is impossible to overrate its value. Upon the completeness of the carriage the gun depends for the due development of its destructive power. We may accept it then as an axiom, that the carriage complete should be so constructed as to qualify the gun effectually to cover with its fire the most extended area of country in the shortest period of time which the surrounding conditions and the highest attainable mechanical skill will render possible. It will be readily understood how large a field of experimental research must have been explored in seeking a satisfactory realisation of these requirements.

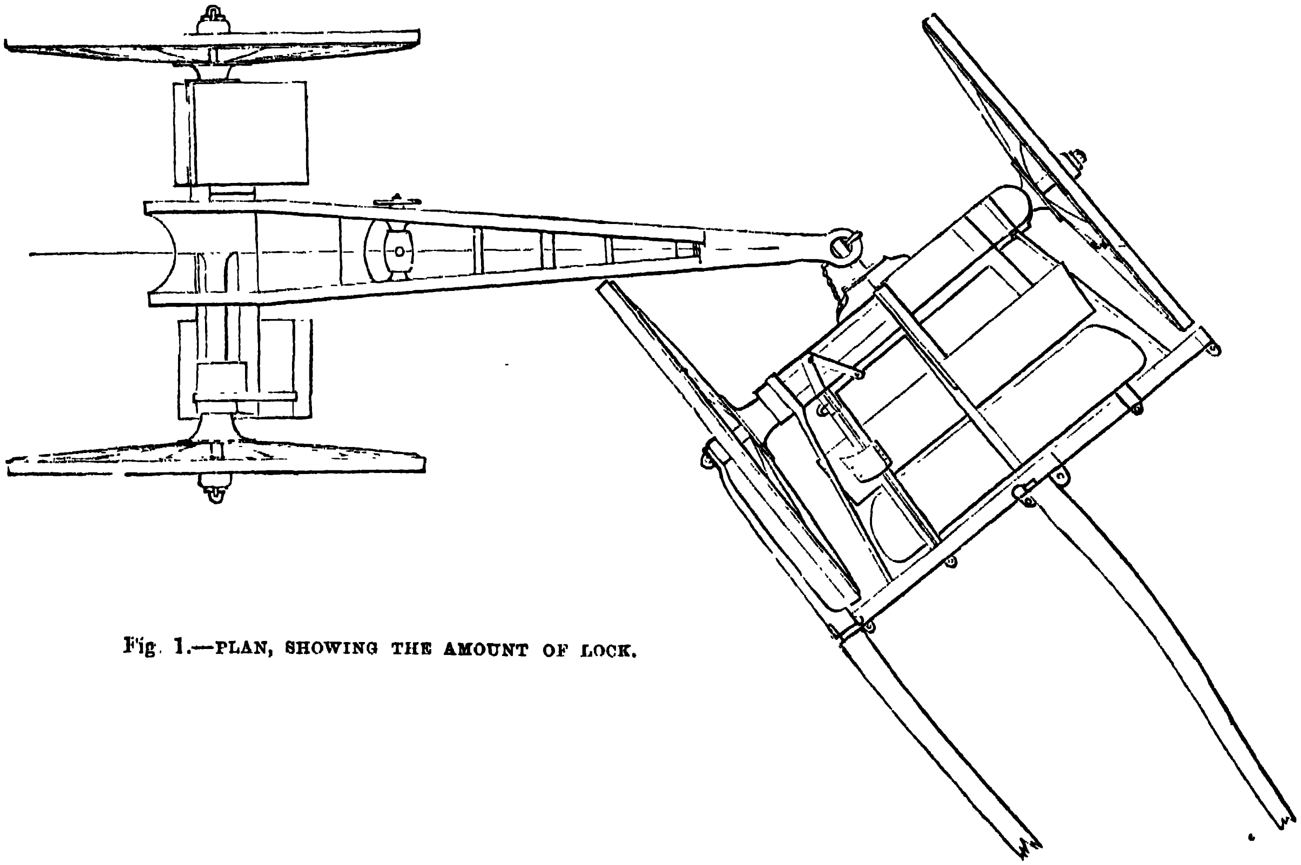


Fig. 1.—PLAN, SHOWING THE AMOUNT OF LOCK.

To adopt a simple method of classification, all artillery carriages may be included under one of two heads, according as they are intended for "field" or "garrison" service. These two chief denominations divide themselves into several subordinate varieties, such as carriages for mountain warfare, for guns of position, and siege artillery—the two first of which are closely allied, as regards general construction, to field artillery carriages proper; and in the third we find some natures assimilating to field, and others to garrison carriages.

The broadside and turret carriages of the Royal Navy, too, in their general features resemble some features belonging to garrison artillery; though in the former mechanical skill has been necessarily exerted to a greater extent than in the latter, with a view to ensuring, under the more difficult conditions of ship-board, an equally perfect control over the guns with that which is obtained on land.

Without entering too minutely into manufacturing details, it is proposed to review the general principles which must be followed in the construction of the two classes of carriages above mentioned, showing also how in obedience to these principles the present forms have come to be adopted.

CARRIAGES FOR FIELD ARTILLERY.

The principal conditions to be fulfilled in a field artillery carriage are—

1. That it shall furnish a convenient and secure support to the gun, both when in action and when travelling.

2. That it be of a form easily handled and manageable, to give direction to the gun when in action.

3. That it be adapted for rapid movements, in conveying the gun not only over good roads, but also over rough and broken country.

4. That provision be made for an ample supply of ammunition and stores, easily accessible to the men serving the gun; also that provision be made for the conveyance, when necessary, of a proportion of these men.

5. That its construction shall be sufficiently strong and durable to resist the statical and dynamical strains and varieties of climatic action to which the contingencies of warfare may expose it.

6. That it shall admit of being readily taken to pieces and conveniently stowed on board ship, a condition which is peculiar to the military carriages of our country.

With respect to the first condition, as field guns have trunnions, a very simple form of carriage can be adopted; all that is needful, so far as the connection between the gun and its carriage is concerned, being a frame supporting the trunnions in such a manner as to allow the gun freedom to rotate about their axis through a sufficient angle for any elevation or depression that may be necessary in laying it. This is secured by providing semi-circular trunnion-holes on the upper surfaces of two cheeks or "brackets," which are separated above from

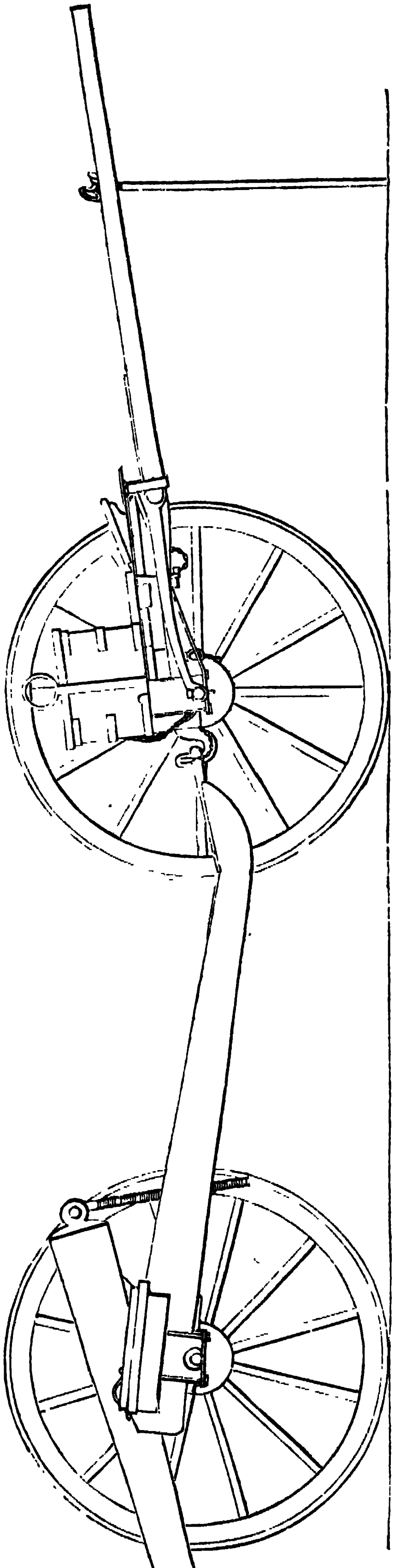


Fig. 2.—FIELD-CARRIAGE, "LIMBERED UP."

each other at such a distance as will just allow of the gun working freely between them through certain prescribed angles, and rigidly connected beneath either by cross-pieces termed "transoms," or by a solid block called the "trail," of which more will be said presently. It is highly important that the gun should be elevated and depressed in a vertical plane, this condition being essential to accuracy of fire at long ranges; the common axis, therefore, of the trunnion-holes must be horizontal when the carriage stands upon even ground.

The third and only remaining point of connection between the gun and its carriage is at the cascabel, where there is an appliance for elevating and depressing the gun with great nicety, at pleasure. The more modern-designs of field-guns having little or no preponderance, there is but little strain thrown on the elevating arrangement either in travelling or firing, as compared with that which the trunnions exert upon the brackets. As respects the stability of the carriage, it is evident that it must have at least three points of support for standing securely on the ground. Two of these are at once supplied by the wheels on which the carriage travels, and the most suitable position for a third remains to be determined. On firing the gun, a violent shock or impulse is communicated to its carriage in a direction exactly opposite to that in which the shot travels. The third point of support then must necessarily be behind the gun, and so situated as to check any tendency in the carriage either to turn round to the right or left, or to turn over backwards at the moment of firing. To answer the first of these requirements, the point must be selected in the same vertical plane in which the axis of the bore lies, and for the second it must not be within a certain distance from the trunnion of the gun, this distance being fixed by the angle which an imaginary straight line perpendicular to the axis of the trunnions, and connecting it with the third point of support, makes with the ground-plane. This angle, it is found, should not exceed 21°. If the rear point of support were brought nearer to the trunnions the angle would increase, and with it the tendency of the carriage to capsize backwards on firing. This angle is in effect the limiting angle of friction for field-gun carriages. The rear point, then, is well behind the gun; its connection with the body of the carriage is secured by a substantial beam called the "trail," which is strongly joined to the axletree in front, and rests on the ground behind. All that is needed for the stability of the gun and carriage, when the latter stands ready for firing, is that the vertical line passing through their centre of gravity should fall within the triangle formed by their three points of support. In practice it is found that if the gun is balanced just over the axletree, so that the axes of both trunnions and axletree are nearly in the same vertical plane, the conditions of stability are secured. By this arrangement the pressure of the rear end of the axletree on the ground is about one-half of its own weight.

So far, then, as respects the stability of the gun and carriage, both when firing and when ready for firing, the conditions are realised in a two-wheeled carriage provided with a trail of suitable dimensions. The next question for consideration is, how would such a carriage travel? It will be at once evident that, excepting for very light guns, a carriage such as now described on two wheels only would be inadmissible, for this reason—the pressure exerted by the trail on the ground when in the firing position, would when travelling have to be sustained by the horse; and in the ordinary descriptions of field-carriages the weight and unwieldiness of the trail alone would be a serious objection to such a method of draught, and the means of attaching and detaching the horses would be correspondingly clumsy. We conclude, then, that a gun-carriage provided merely with two wheels and a trail body, while exhibiting an excellent combination for firing purposes, is altogether ill adapted for travelling, excepting when applied to very light artillery such as that designed for mountain service. Here a proportionally light carriage is needed, to the trail of which a pair of shafts can be readily attached, their combined weight being supported with ease by the draught animal, which is generally a mule.

In the field artillery, therefore, an additional pair of wheels for the support of the end of the trail becomes necessary when travelling, and the result is a four-wheeled carriage. It so happens that the construction we have seen to be very suitable as a standing carriage, offers great facilities for being converted at will into a simple and efficient form of travelling carriage. All that is needed for this purpose is to procure an independent fore-carriage to which the horses are harnessed. Attached to the centre of the hind part of this carriage is a strong hook. To the end of the trail of the gun-carriage proper must be fitted a suitable iron loop. This is known as the "trail eye." Lifting the end of the trail off the ground to a height just above the level of the hook on the fore-carriage, the hook is brought under the trail eye, which is then lowered down into it, and secured by a horizontal key which passes through the end of the hook. We are thus provided with a strong and well-constructed four-wheeled carriage. The fore-carriage is known as the "limber;" the process of connecting the trail with it is called "limbering up" (Fig. 2), the converse of which is "unlimbering." The limber, whether attached to the gun-carriage or acting independently, is equally available for movement. In one case it acts as a fore-carriage, in the other as a cart, so far as the arrangements for travelling are concerned. The shafts, which are rigidly connected with the body of the limber, take a share with the wheels in supporting its weight and maintaining it in the proper travelling position. When the carriage is unlimbered, the weight on the shafts is rather excessive, but this is counteracted when in the travelling position by the weight of the trail acting on the hind part of the limber, and thus counterbalancing the otherwise great preponderance on the shafts, which would act injuriously on the shaft-horse. It is not contemplated that the limber should be required to travel far when detached from its gun-carriage. The undue weight on its shafts when thus detached is therefore a matter of little moment.

We have seen that in order to secure stability in the firing position a certain length of trail is indispensable, and that the entire weight of gun and carriage must be so distributed as to bring upon the point of the trail about half its own weight. As the trail must be lifted by hand for the purposes of limbering up and unlimbering, the weight to be raised should be restricted within the lowest limits compatible with the requirements of stability and strength; its length should therefore not exceed these limits, and its weight must be no greater than what is necessary to ensure sufficient strength to resist the shocks incurred in travelling and firing. In the construction of every kind of vehicle, the minimum of weight consistent with a necessary reserve of strength is the object desired. These properties, lightness and strength, are primarily antagonistic; and the form adopted is in effect that to which science and experience point as being the most effective compromise between them. Again, the length of the trail must be sufficient, and only sufficient, to admit of a free passage between the wheels, in order to gain access to the trail-eye and limber-hook. The space between the front and hind wheels is, of course, dependent upon the length of the trail. It is essential also that the carriage should be short, both on account of covering as little ground as possible when turning, and in order to diminish as far as practicable the length of a column when marching along the road.

Regarded on its merits as a four-wheeled vehicle, one point is especially worthy of notice in the field-carriage. The form of the gun and its particular functions admit of the trail being made extremely narrow, assimilating to the perch of an ordinary carriage. This construction, without sacrificing the advantages secured by a high front wheel, affords ample facility for changing direction. The limber can be turned to the right or left, about the trail-eye, as a centre, through a considerable angle before its wheel comes in contact with the trail, as in Fig. 1. Thus it will be seen that this form of carriage claims for itself almost exclusively the following advantageous combination :—1. A low body. 2. Good locking power. 3. High front wheels. This combination secures pre-eminently the all-important qualities of stability when travelling, and handiness in turning; also a further advantage, which will be presently considered as fulfilling in a great measure the third essential condition which was stated in the onset—namely, the capability of rapid movement.

With reference to the second condition, requiring that the gun should be handy when in action, the two points to be considered are—(1) facility for turning the gun horizontally; (2) in a vertical direction. 1. To turn the gun horizontally, to the right or left, there is an iron staple or shoe fixed upon the end of the trail just above where it rests on the ground. Into this shoe a handspike, which is always carried with the carriage, is stepped, and is so curved that its point or handle shall be raised to a convenient height for a man to take hold of when standing by it. One man is able with tolerable ease to lift the weight of the trail sufficiently off the ground to enable him to move it either to the right or left, causing the gun to turn horizontally about an imaginary vertical axis, equidistant between the wheels, thus giving any horizontal direction that may be required. 2. The vertical direction, or elevation, is obtained by raising or depressing the cascabel. This is effected by an elevating screw, the upper end of which is attached to it, and which works in a female screw below, made to revolve by means of a small hand-wheel worked on the right bracket of the trail. The gearing is so constructed that a very slight effort with one hand suffices to raise or lower the gun.

With regard to the third condition—namely, the adaptability of the carriage to rapid movement—it has already been observed that high wheels can be used: we will now proceed to illustrate the advantages which they confer. High wheels, if not very ponderous, contribute greatly towards easing the draught. This they do in a twofold manner; first by diminishing friction, and secondly by spanning ruts and hollows on the surface of the road in such a way as to offer less resistance than smaller wheels would offer to the progress of the vehicle. It has been proved by experiment, and is capable of mathematical demonstration, that the traction or pull of the trace is diminished by increasing the height of the wheel. The ease with which horses can draw a carriage increases *with*, though not *as*, the radius of the wheels. If, for instance, a horse harnessed to a cart with wheels of fifteen inches radius draws the load with a pull on the trace amounting to twenty pounds, the pull on the trace would not be halved by doubling the height of the wheels—giving them a radius of thirty inches—but it would be very materially diminished. On ordinary roads, where a succession of trifling obstacles are encountered and surmounted by the wheels, the pull of the trace would be reduced probably from twenty pounds to thirteen pounds by doubling the height of the wheels. Hence, though the advantage to the draught is not directly proportional to the height of the wheels, it is nevertheless very greatly dependent upon their height; and thus it is highly important to maintain the wheels of field artillery carriages at the greatest diameter which the limits of convenience and moderation in weight will permit. The experience of the British artillery has given a sanction to five feet as being the most suitable height of wheel for the artillery service; and with this height of wheel the limber can lock round through an angle of about 52°, giving the carriage abundant facility for turning on ordinary roads, and in manœuvring on the field. This advantageous combination of a high front wheel with a good lock is simply due to the narrowness of the trail, which when the gun is limbered up may be said to take the place of the body of an ordinary wagon

If we turn for an instant to the construction of ordinary wagons, the difficulties involved in securing this combination will perhaps be more readily seen. Nearly every wagon used on ordinary roads at the present day is furnished with front wheels which pass freely under the body—a standing acknowledgment of the importance of good locking power. In order to secure this, however, whilst maintaining a tolerably low position of the body, the front wheel must also necessarily be low to pass under it, very much lower than the hind wheels, the position of which relatively to the body never alters. Now, on the excellent macadamised roads of England, a low front wheel, though objectionable, is not of so very much importance, especially when the wagon is on springs. The first two points of the combination before mentioned are secured; the third is sacrificed. Experience has proved this arrangement to be the best suited for ordinary traffic on good roads. For military service, however, the circumstances are widely different. The carriages accompanying an army in the field must often follow the worst of roads, and not unfrequently across country. Every contrivance, therefore, by which the draught can be lessened must be carefully studied. It is accordingly highly fortunate that the peculiar construction of the gun-carriage does not necessitate a low limber-wheel.

The fourth essential condition is secured by carrying thirty rounds of ammunition complete in two boxes, which are placed on the limber. In addition to these four rounds of case-shot are carried, in two small boxes, on the axletree of the gun-carriage. Each gun is accompanied on service by an ammunition wagon, consisting of a "body" and a limber, which latter is identical and interchangeable with the limber of the gun-carriage. The wagon-body has a perch made of girder-iron riveted securely to the axletree-bed. This perch occupies the place of the trail in the gun-carriage, and, like it, is attached by an eye to the limber-hook. The wagon-body has four ammunition boxes, and its limber two, each containing fifteen rounds of ammunition, making in all ninety rounds. Thus each gun-carriage, accompanied by one wagon, has a supply of 124 rounds of ammunition. This quantity is considered ample for immediate wants, reserves being always in readiness to replenish the wagons as they become exhausted. The limber-boxes are fitted as seats for the conveyance of two, or possibly three men on each limber. In the horse-artillery the remaining members of the detachment serving the gun are mounted. In the field-artillery they march on foot except on emergencies, when two additional gunners sit on the axletree-boxes of the gun-carriage, and others can be mounted on the off-lead and centre horses drawing the gun.

With reference to the fifth condition, it will suffice to say that the dimensions of the various parts of the gun-carriage have been arrived at through the experience of actual warfare, combined with careful calculation. Excepting in the spokes and felloes of the wheels, and the axletree-beds, foot-boards, and bottom-boards, no timber takes any part in the construction.

In the gun-carriage the brackets of the trail are made of plate iron, with angle-iron framing. The body of the limber, excepting the axletree-bed, is also of wrought iron. By a judicious disposal of the iron, the requisite strength is secured without excess in weight. The weight of the 9-pounder gun-carriage and limber packed complete is about 35 cwt. As to durability, it may be affirmed that, with attention to prevent rusting, the carriages and wagons are in all their main parts practically indestructible.

With respect to the sixth and last condition—namely, that of packing on board ship—the ammunition boxes are readily removed; and when the carriages, limbers, and wagons are dismounted from their wheels, an entire battery can be stowed away in very little space, considering the large quantity of stores it includes.

Reverting to the fourth condition, it may be as well to state that every convenience for carrying side-arms, intrenching tools, and small stores is applied both to gun-carriage and wagon with their limbers; and, indeed, up to the present time a full complement of tents for the accommodation of each gun detachment has been carried on the wagons—an admirable arrangement, and one highly conducive to the comfort and health of the soldier.

BUILDING CONSTRUCTION.—XVIII.

ROOFS—ARCHED RIBS.

In fixing the ribs of the dome of the Catholic church at Darmstadt (see page 138) in their places, the plates were, in the first place, merely nailed together; they were afterwards permanently connected, and prevented from altering their shape by bands of timber (*b b*, Fig. 173) running all round at regular heights; and these are bolted together as shown at *c c* (Figs. 174 and 175), the plates being further prevented separating laterally by the cross-pieces, *d d* (Fig. 174); the ribs are further stayed by additional bands running all round through the middle of their width. The openings for these timbers are shown in Fig. 173, and all the parts will be seen in their proper places in Fig. 176, which is a view of a portion of a dome, showing the lower ends of the main ribs, A A, and of an intermediate rib, B. The external and internal bands, *b b*, will be seen notched on to the ribs and united by the bolts, *c c*, at the sides of which are also seen the wooden cross-pieces, *d d* (Fig. 174); *c c* is the intermediate band, with wedges, *d d*, the purpose of which is to cramp the plates together laterally. The proper mode of projecting such views of domes will be given in a subsequent figure, it being desirable, at this stage, to contrast the De Lorme system with that of Emy.

This system has already been described and illustrated in former lessons, and it will therefore be sufficient to show how it has been applied. The example (Fig. 177) chosen for this purpose is a portion of the roof-truss of the riding-school at Libourne, near Bordeaux. The roof is not of the dome kind, but covers a building of a rectangular form.

The arch-rib, built up of five plates placed horizontally on each other, and joined as already shown, abuts against perpendicular double-posts, A, resting on corbels, B, built into the wall, which is one-third wider below than it is above this point. At the top of this wall-post is a strong cross-piece, C, resting on the stone cornice, D, which covers the whole width of the top of the wall; and this in its turn is laid on the wall-plate, which is placed on the *outer* face of the wall, so that it will be seen that the entire weight of the roof presses *downward*, or in the direction of the wall, and that the tendency of the whole truss must be to tie the walls together, not to force them outward; and this, as has already been explained in a former lesson (page 37), is the leading point to be kept in view in designing a roof. The principals, E, abut upon the cross-pieces, C, and are tied to the perpendicular by the struts, F, and to each other at the top by the collar-beam, G. To the frame thus formed, braces, H, I, J, etc., are attached, *converging to the centre of the arch-truss* (these braces are double), and clasp the arch-truss, the principals, and the ties, F, between them—being themselves bound together by means of blocks and bolts, the ends of which are shown in the illustration. The arch-truss is confined at the foot of the wall-post by an iron band, tightened by a screw-bolt. This arrangement is shown in Figs. 178 (the section), 179 (the side elevation), and 180 (the front elevation).

PARTITIONS.

Partitions are the internal walls which divide the building into separate rooms, and may be formed of solid walling, of timber framing filled in with brickwork, or may be made wholly of timber and covered with boarding or laths and plaster. This latter kind will be here considered. Partitions must be constructed on proper principles of trussing, so as to guard against cross strain, especially when placed over a vacuity without any support but at the ends, or when having to bear the weight of a floor above it.

Partitions should form a portion of the main carcase of the building, and should not be dependent upon, but should rather support the flooring. An important form of partition is given in Fig. 181, which represents a 6-inch partition so trussed as to support a floor above. It will be seen that A B C D is a complete roof truss, with queen-posts E, principal rafters F, and straining-piece G. This truss rests on stone templates in the wall. The sill at the bottom of the partition rests on a brick corbel built out of the wall, and on this is placed a stone template and an iron clamp. This supports a wooden wall-plate, or template, to receive the end of the sill.

The middle part of the partition is further to receive folding doors. The upright posts for this opening are placed under the queen-posts, are kept apart by a straining-piece, and pressed together at the top by braces, I I, which, being mortised into the sill, act as principal rafters again, and thus a second truss is formed under the other; whilst the whole structure is firmly braced up by the iron tie-rods at K, K.

FIRE-PROOF CONSTRUCTION.

A *perfectly* fire-proof construction has yet to be discovered, and therefore the author, guided by the best authorities of the day, of which Mr. Hoskings must rank as one of the highest, quotes from him the following remarks on fire-proof structures:—

"It is seldom that houses take fire from common accidents, such as occur to the lighter movable furniture and to drapery, but for the most part from the exposure of timber in or about the structure to the continued action of fire, or of heat, capable, sooner or later, of inducing the combustion of timber; and as the source is most commonly in some stove, furnace, flue, pipe or tube for generating or conveying heat, or for removing the products of combustion, much of the real danger to buildings by fire would be prevented by avoiding that degree of proximity between timber and all such things as can lead to its combustion.

"With the view of rendering their stairs, partitions, and floors as nearly as possible fire-proof, the French frame and brace with timber quarterings, much in the manner practised in England, excepting that the timber used in Paris is generally oak, previously well seasoned. The frame structure being complete, strong oak batten laths, from two to three inches wide, are nailed up to the quarterings horizontally, at four, six, or even eight inches apart, according to the character of the work, throughout the whole height of the enclosure and partition; and the spaces between the quarterings and behind the laths are built up with rough stone rubble, which the laths prevent falling out until the next process has been effected. This is to apply a strong mortar, which in Paris is mainly composed of plaster of Paris, which is there of excellent quality, laid on from both sides at the same time, and pressed through the opposite sides, so that the mortar meets and incorporates, embedding the stone rubble by filling up the interstices, and with so much body on the surface as to cover up and embed also the timber and the laths; in such manner indeed as to render the concretion of stone and plaster, when thoroughly set, an independent body, and giving strength to, rather than receiving support from the timber. The ceilings are constructed on a somewhat similar system. According to their practice, the ceiling must be formed before the upper surface or floor is laid, being formed from *above* instead of from below. The carpenter's work being complete, strong batten laths are nailed up to the under side of the joists, as laths are with us; but they are much thicker and wider than our laths, and are placed so far apart that not more than perhaps one-half of the space is occupied by the laths. The laths being affixed—and they must be soundly nailed, as they have a heavy load to bear—a platform of rough boards is strutted up from below parallel to the plane formed by the laths, and at about half an inch below them. Mortar is then laid in from above over the platform, and between and over the laths to a thickness of from two and a half to three inches, and is forced in under the laths and under the joists and girders. The mortar being gauged, as our plasterers call it, or rather, in great part composed of plaster of Paris, it soon sets sufficiently to allow the platform to be removed onwards to another compartment, until the whole ceiling is formed.

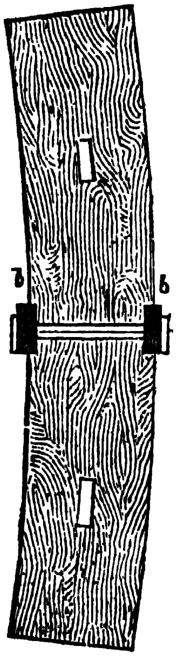


Fig. 173.

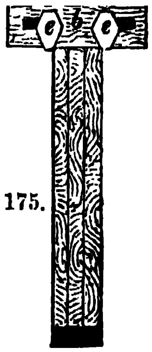


Fig. 175.

"The plaster ceiling thus produced is in fact a strong slab or table in the body of which the batten-laths which hold it up are incorporated, and in the back of which the joists from which the mass is suspended are embedded. The finishing coat of plaster is then laid on. Such a ceiling will resist any fire that can act upon it from below under ordinary circumstances, and it would be difficult for fire to take hold from above in such a manner as to destroy the joists to which a ceiling so composed is attached, the laths and the under side of the joists being alike out of its reach; and consequently such a ceiling alone would diminish the danger of fire, although the floor above the joists were laid with deal boards.

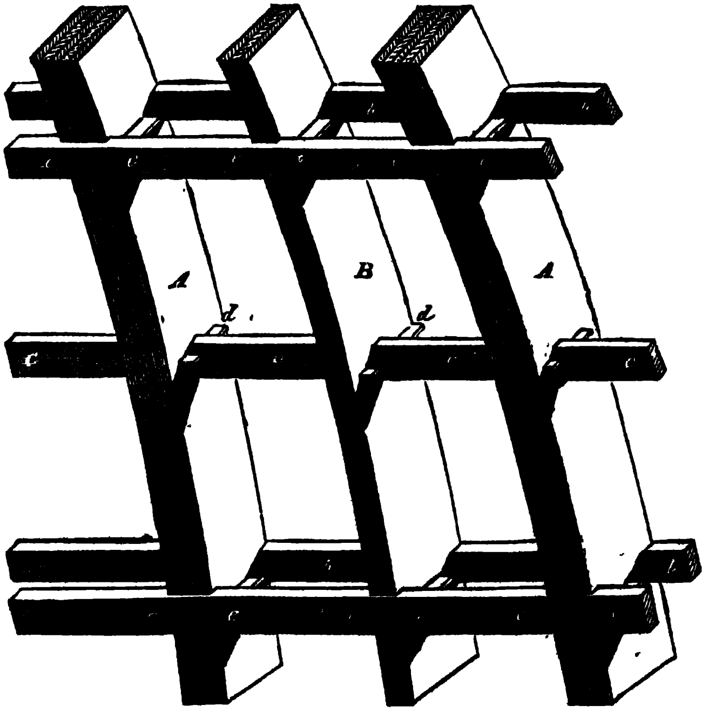


Fig. 176.

"But a boarded floor in Paris is a luxury not to be found in the dwellings of the labouring classes, nor indeed is it to be found in any dwelling house but those of the most costly description. But whether the eventual surface is to be a boarded floor or not, the flooring-joists are covered by a table of plaster above, as completely as they are covered by a plaster-ceiling below. Rough battens, generally split, and in short lengths stout enough to bear the weight of a man without bending, are laid with ends abutting on every joist, and as close together as they will lie without having been shot or planed on their edges. Upon this rough loose floor mortar of nearly similar consistence to that used for ceilings is spread to a thickness of about three inches, and as it is made to fill in the voids at the ends and sides of the floor-laths upon the joists, the laths become bedded upon the joists, whilst they are to some extent also incorporated with the plaster. The result is a firm floor upon which in ordinary buildings paving-tiles are laid, bedded in tenacious cement.

"It must be clear that the timbers of a floor so encased could hardly be made to burn, even if fire were let in between floor and ceiling. But it has been already stated that the practice of making these almost fire-proof floors is connected with the use of walls which have no timber laid in them bed-wise, and that the timber enclosures employed instead of walls and the internal partitions are rendered practically fire-proof, whilst the wooden staircases which economy dictates to the Parisian builders (the freestone which is used in building the walls being wholly unfit for the purpose) are also rendered unassailable by fire by being filled in with a solid mass of concreted rubble."

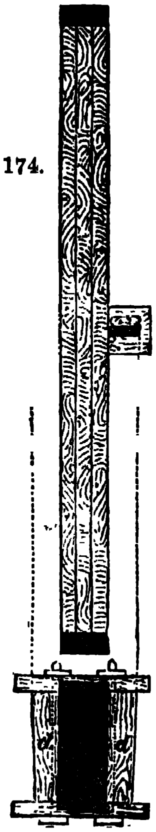


Fig. 174.

The author has thought it advisable to quote the above remarks of Mr. Hoskings on this subject, in the hope that, if it can be proved statistically that a smaller number of dwellings are accidentally destroyed by fire in Paris than in London, the system here described may be introduced into this country.

It must, however, be added that the subject of fire-proof construction has within recent years received much attention in England, and it is hoped it may become more generally adopted. One of the plans patented is based, firstly, on the use of wrought-iron girders combined with concrete, the patentees urging that for any part of a structure to be fire-proof all the materials employed should be absolutely indestructible, and hence no wood should be employed in the absolute construction; though when the fire-proof floor is completed fillets of wood may be bedded in the cement on the surface for the attachment of a carpet, or may even be continued across the room and boards nailed to them, as in the French system.

The iron girders, joists, and T-bars are fitted together before delivery, and after the main girders are fixed any boy or labourer can complete the work. The concrete should be mixed thick like the French *béton*, a flat board being held up underneath the T-bars whilst spreading it between the joists and girders. A concrete made of Portland cement or blue lias lime with gravel, ballast, or broken brick, in the proportion of one part of the former to eight of the latter, sets quickly and becomes as hard as stone, The upper surface may be finished in fine cement, and the notched or slotted ends of the bars sustain the plaster under the flanges of the joists and girders, where there is a tendency to break away when any vibration takes place.

Independently of the fire-proof condition of floors constructed in the manner just described, there are other advantages to be derived from this mode of structure. In the first place, the access of rats and mice from one part of the house to another would be almost entirely if not wholly prevented, the spaces usually left between the flooring of the room above and the ceiling of the room below, the bad and hastily-mixed mortar commonly used in ordinary houses the imperfect manner in which it is frequently laid between the bricks or stones of the structure, and the hollow, unplastered interval left between the skirting-board and the wall, affording ample opportunity for these vermin to make their way from cellar to attic at pleasure. Again, floors of concrete would prevent free passage of draughts and dust, which now make their way through shrunken boarded floors, and necessitate the placing of a layer of brown paper to save the carpet from injury by dust. On the other hand, concrete, finished with cement, being a better conductor of heat than wood, affords an argument in favour of covering flooring of this description with an exterior coating of planks, a carpet only between the concrete and the feet of the occupants of the room being barely sufficient to insure thorough protection from the chill that concrete would impart.

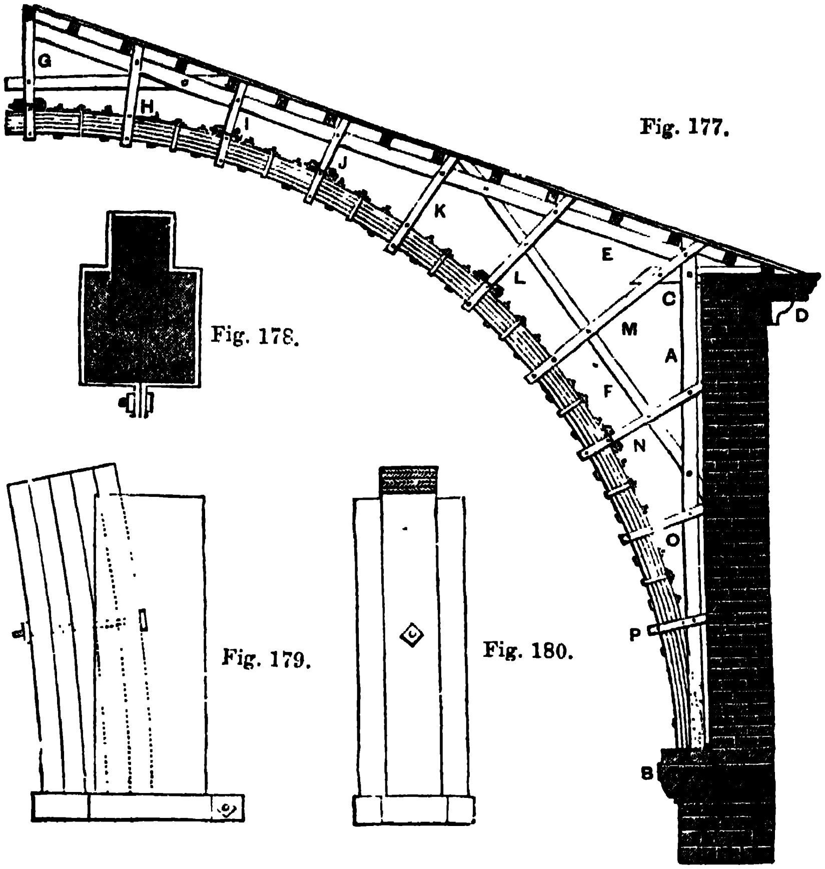


Fig. 177.

Fig. 178.

Fig. 179.

Fig. 180.

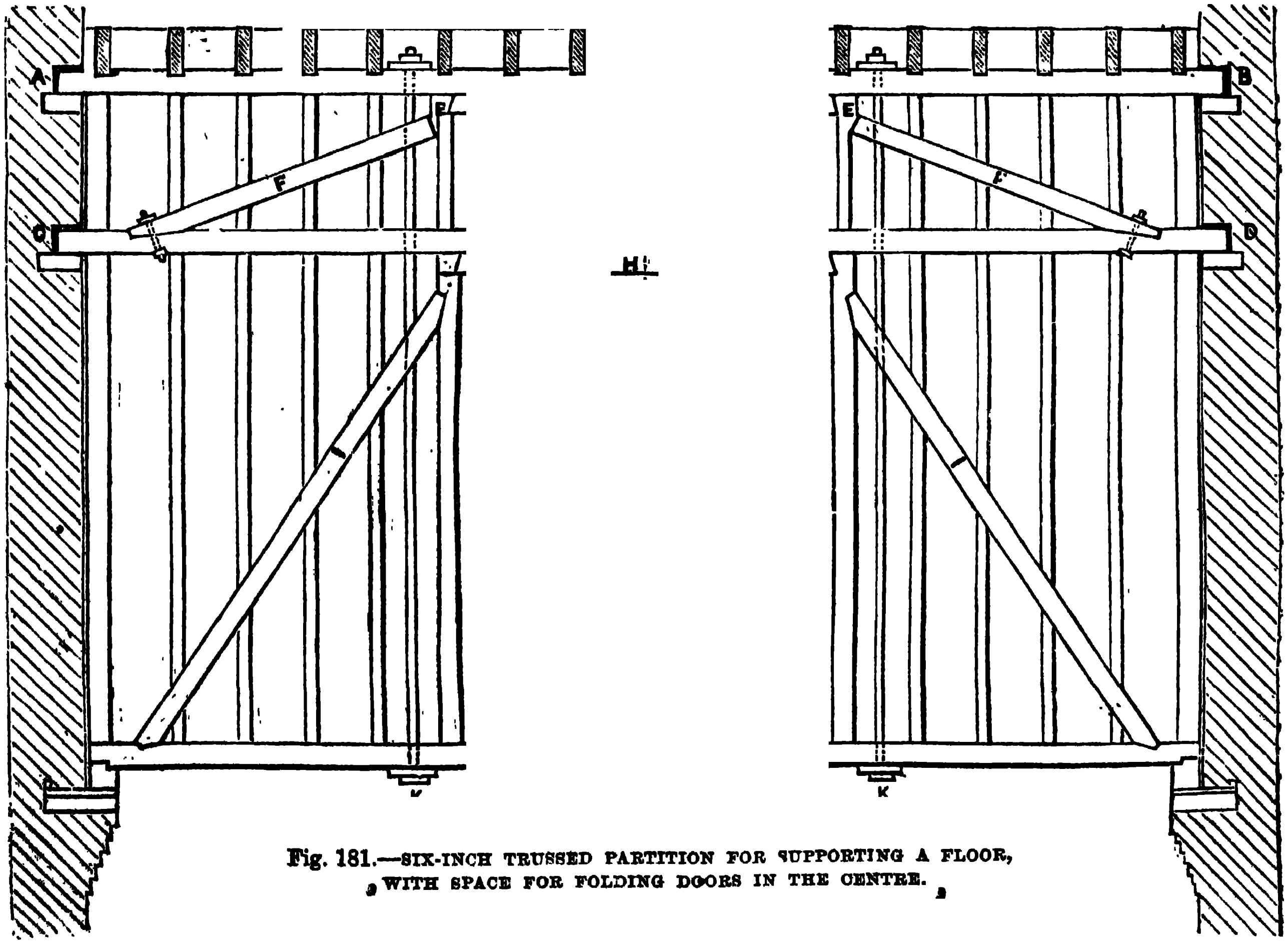


Fig. 181.—SIX-INCH TRUSSED PARTITION FOR SUPPORTING A FLOOR, WITH SPACE FOR FOLDING DOORS IN THE CENTRE.

FARMING AND FARMING ECONOMY.—II.

By Professor Wrightson, Royal Agricultural College, Cirencester.

PREPARATORY WORK IN SOILS—DRAINAGE—CLAY BURNING—LIMING—SUBSOIL AND TRENCH PLOUGHING, ETC.

Rural economy touches all the three kingdoms into which natural objects have been divided. Its foundation rests upon inorganic nature, whence, through the agency of incomprehensible laws, rises the vegetable world, and, lastly, by a further and more complex elaboration, animal life. As if to complete this cycle of change, the animal finally dies, and is restored to the inanimate domain, its component parts ministering anew to the development of future organisms. First, the soil, the air, and water afford scope for study; secondly, the cultivated crops form an interesting group; and, lastly, the live stock of the farm represent the animal kingdom. Every study, therefore, which bears upon these widely different subjects, becomes important to the student of agriculture; and hence we find chemistry, physics, and geology, physiology, botany, and zoology, all to some extent engaged in promoting agricultural advancement. In the following series it must be our object to restrict our attention to farming and farming economy, and to avoid the temptation of wandering into the domain of these and other sciences. In following our subject, we shall adopt the natural order already indicated, and consider (1) the soil, (2) crops, (3) stock, and, lastly, certain subjects connected with land management which do not strictly come under any of these heads.

Soil has been derived from previously existing rocks, which, during long ages, have been worn away and disintegrated by the continual action of natural forces. Hence the intimate connection of geology with agriculture; for, as rocks of various composition constitute large and distinct areas of country, so do we find the soil to vary. Chalk, green sand, oolitic limestones, Oxford and Kimmeridge clays, each furnish soils of definite character, varying in fertility, in tenacity, in altitude, and in other particulars.

All soils, wherever situated, are composed of clay, sand, lime, vegetable matter, and rocky fragments, and it is upon the proportions in which these familiar substances occur that fertility in a great measure depends. A fertile soil must be placed under favourable climatal conditions, both with reference to heat and moisture; it must possess an abundant store of available plant-food; and it must be in a proper mechanical condition. Heat and moisture are scarcely capable of control, while, on the other hand, the amount of plant-food and the physical or mechanical condition of the soil may be increased and improved. Hence we find two methods open to us in improving land—first, enriching the chemical resources of the soil, by adding to it substances valuable to plants as food; and, secondly, improving the mechanical condition of the soil. A soil may possess every necessary constituent for the growth of plants, but if these are unavailable we can hardly expect to see good crops upon it. If, for instance, the soil is wet or exceedingly tenacious, then, in spite of its good chemical composition, it will be more or less barren. Thus the improvement of the mechanical condition of the soil is fully as important as the addition of fertilising substances. Without further preface, therefore, we pass on to consider the methods ordinarily employed for improving the physical state of soils.

All soils do not require this preparatory work. Take, for instance, the case of light, dry land, in which the proper chemical substances occur in sufficient quantity. Such a soil will quickly repay the farmer for the expense of manuring; and this being the case, it is no matter of wonder that the lighter soils of this country have been long well farmed. The case of clay soils is somewhat different. They are richer than light soils in chemical constituents, but these riches are difficult to reach. More capital is therefore required to cultivate such land, and a longer time is necessary to bring it into a satisfactory condition. It is, therefore, in the management of clay lands that the preparatory work of mechanical improvement is most needed, and even after it is accomplished continual care is requisite so that every tillage operation may tend to induce a state of perfect tilth.

The means for the amelioration of soils are as follow:—(1) Drainage; (2) clay-burning; (3) claying, marling, and mixing; (4) liming; (5) warping; (6) subsoil and trench ploughing; (7) good cultivation.

Drainage is of all these the most important, and should precede every other operation. If land is wet, capital is uselessly expended upon it; but when rendered dry, every other improvement is likely to be followed with success. The subject of land drainage has been so recently placed before the readers of The Technical Educator, that it appears hardly necessary to revert to it at length. It may, however, be well to remind our readers that an efficient system of drainage is followed by a distinct rise in the temperature of the soil, by the introduction of air into interstices previously occupied by stagnant, and therefore unwholesome, water; by an evident improvement in the texture of the soil, and by the rainfall being rendered effective in assisting in the growth of plants, instead of absolutely checking vegetation, as must be the case in waterlogged soils. These good effects are followed by earlier and more abundant harvests, capability to grow a larger variety of crops, improved health on the part of both crops and live stock, and greater ease in the performance of all tillage operations. The soil is also in a better state for benefiting both by application of manure and other improvements.

Clay-burning is a valuable means of rendering stiff land productive. It consists either in burning large masses of clay, or smaller heaps of about one cart-load each, and afterwards spreading the "ashes" upon the surface. Mr. Mechi uses a strong Ransome's plough, drawn by three horses abreast. "The earth being ploughed up, the fires are formed on the spot, the workmen placing a certain quantity of dried stumps, or wood of sufficient solidity, to maintain a body of heat, and enclosing the mass with large clods. These are carried by hand. Subsequently, as they get more distant from the fire, a barrow is used, and beyond that, a one-horse cart." Heaps of 200 cubic yards each are thus burnt. Mr. Pyne, in a communication to the late Mr. P. Pusey, says, "The work begins in May, and is continued throughout the summer." He employs "roots and brush-fagots," and the cost of the wood is about 10s. for every 100 yards of clay burnt. Mr. Randell, of Chadbury, is a strong advocate for this means of improving land, and advises every tenant of stiff soil to adopt it. He considers fagots to be preferable to coal as a means of burning clay, because the soil is not burned so hard as is frequently the case where coal is used. One toni of coal will, with care, suffice for fifty cubic yards of clay. In clay-burning it is essential that the heat should be moderate, and that the work should not be hurried. The fire is kindled as above described, and as the heat spreads through the mass more clay is added, especially to those parts where the fire shows a tendency to break through the walls of the clump.

"In clay-burning," writes a correspondent to the late Philip Pusey, "great skill, and judgment, and management are necessary. Indeed, I know of no part of husbandry that requires so much good sense, joined with experience." Mr. Randell also states that clay-burning requires great experience, and that without experience descriptions of the process are but of small utility. All writers are agreed as to the advantage of large heaps or clumps, of slow burning, and of encouraging a comparatively low rather than a high degree of heat.

Should the wind rise, thatched hurdles are used to prevent the fire from being unduly fanned; and if the flame should appear at the surface, fresh soil is added to smother it. Mr. Randell guards us against the use of large lumps, which will harden into intractable masses, but other writers do not agree with him in this last point, and speak of the lumps as readily falling under the influence of rain and changes of temperature. The cost is very uniformly calculated at about 7d. per cubic yard in the heap, but must vary with the price of coal or the value of wood used in burning. The effects are a larger yield of produce, the land more easily worked, and in many cases a considerable extension of root-cultivation and of sheep-farming. Dr. Voelcker experimented upon the changes effected in clay by burning, and showed that, when exposed to a low red heat, the amount of matter soluble in water was considerably increased. When the heat was increased to bright redness, the soluble matter diminished to even a less quantity than in the unburnt clay. Judicious burning, therefore, acts both in improving the texture by rendering the clay less tenacious, and also by improving its chemical condition.

Claying, *marling*, *chalking*, and in general *mixing*, soils may all be used with great advantage where the requisite conditions occur. It is not uncommon to find such a combination of soil and subsoil that the latter may with advantage be raised and spread upon the surface.

Thus, in Norfolk, marling the sandy surface-soil is attended with great advantage. In Lincolnshire, where fen lands of peaty character occur, the nature of the soil has been greatly modified, and rendered suitable for the growth of cereals, by bringing up the underlying clay. Again, the upper chalk soils may be greatly improved by a dressing of the richer and more tenacious lower chalk; and, lastly, clay soils may be benefited, although in a less degree, by a liberal application of sand, as has been shown by Mr. Hope's treatment of his Dirlton Farm, in East Lothian. The marl, chalk, or clay being at a convenient distance, it is quarried, and carted to the field. In some cases pits and trenches are opened, and the material is brought up and spread on the surface.

Mr. Cambridge, of South Runcton, Norfolk, effected quite a revolution in the character of a light sandy farm by applying 54,055 loads of clay to 286 acres 2 roods 25 poles of land, or 188 loads per acre. In other cases 50 and 80 loads per acre have been employed with good effect. The result of claying and marling is an increase in the fertility of the soil, greater strength in the straw of cereals, more certainty in the cultivation of clovers and root-crops, and a greater power on the part of the soil to resist drought.

Liming is a valuable means of both enriching and improving the texture of soils. It exerts a threefold influence, first as a plant-food, second as an ameliorator of the texture, and thirdly as a neutraliser of acids in the soil. It is, perhaps, most beneficial in the case of newly "broken up" land, especially of a peaty or vegetable character. Lime is also a valuable application for clay soils in general, and where soils are naturally deficient in lime it may be applied at intervals of twelve years with excellent results.

Lime is obtained by heating the carbonate to full redness for an hour or two. For agricultural purposes, the impure (native) carbonate is burned in a kiln, the cavity of which is usually either egg-shaped or in the form of a truncated inverted cone; it is charged with alternate layers of coal and limestone, and the fire is kindled. The lime as it is burned gradually sinks down, and is removed by openings at the base of the furnace, and a fresh supply of coal and limestone is supplied at the top of the kiln. (Miller.)

The following are usual dimensions for lime-kilns:—Height inside of kiln, 21 feet; diameter at top, 7 feet; diameter at middle, 8½ feet; diameter at bottom, 3 feet. The kiln ought to increase in width from the bottom upwards, till the greatest diameter is reached at the height of 11 feet; the walls are then carried up perpendicularly for four feet, after which the space is narrowed towards the top. The building material should be good stone, well built, and the walls should not be less than three feet thick at any part. The inside should be cased with fire-brick, and round the top there should be some large fire-burrs made to pattern, the whole to be well cemented with fire-clay. At the bottom there must be a space two feet square for drawing out the lime, and from the top of this to the outside there must be an archway for facilitating the same. Such a kiln will hold 700 to 800 bushels of lime, and will burn at the rate of 250 bushels a day. To furnish 100 bushels of lime, about 6 tons of mountain limestone and from 25 to 40 cwt. of coal will be required. This will make the cost about as follows (see "Cyclopædia of Agriculture"):—

	£	s.	d.
6 tons of stone, worth 10d. per ton	0	5	0
Say 1 ton 15 cwt. of coal, at 4s. 6d. per ton	0	7	10½
Lime-burner, about 2s. per 100 bushels ...	0	2	0
Kiln tools, interest on capital, etc., say ...	0	1	0
Or, per 100 bushels	0	15	10½

The weight of a bushel of lime varies with the quality of the stone whence it is derived, and is variously estimated at 77 lb., 93 lb., and 80 to 100 lb.

Lime is applied at the rate of from 3 to 9 tons, or from 100 to 300 bushels. It is carted either into large heaps on the headland, where it remains until it is slaked; or it is deposited in small heaps (about ten to the cart-load), covered with a little earth, and then left to slake. In both cases the subsequent work consists in spreading it over the surface, after which it is lightly ploughed or cultivated in.

Warping gives an entirely new surface to soil. It may be best explained as a process by which the suspended mud which occurs in certain rivers is allowed to deposit itself upon a prescribed area of land. The chief district where this improvement can be effected is in North Lincolnshire and South-east Yorkshire, on either side of the Humber and its tributaries. These rivers carry an immense quantity of mud to the ocean, and naturally deposit it at the mouth of the Humber. By a system of sluices, open ditches, and embanked enclosures, the muddy water is diverted during spring-tides, and made to flow where it is required. As the water expands over the "compartment" it deposits its mud; and, by regulating the flow by means of "call-banks" and "inlets," an even coating of from one to three feet is at length obtained. Warping is a costly operation, incurring an expense of from £12 to £20 per acre. It may, however, be regarded as securing permanently good land upon an area which previously may have been almost worthless.

Subsoil and *Trench Ploughing* have been advocated by many agriculturists. Both may be spoken of as valuable means for deepening the available feeding-ground of plants, and both are useful when used judiciously. Indiscriminate deep culture is not, however, to be recommended, as in some cases it might be hurtful, while in others no appreciable benefit follows its adoption. Subsoil ploughing may be defined as a method of disturbing or pulverising the subsoil; while trench ploughing consists in bringing up the subsoil, and mixing it with the surface-soil. Subsoil ploughing is seldom injurious, but the rash commingling of subsoil and soil may be attended with either good or bad effects. A considerable mass of evidence collected by the late Mr. P. Pusey upon subsoil ploughing tended to show that stiff clay soils are not permanently benefited by it, and that the greatest good was effected in the case of lighter soils, where at a few inches beneath the surface some sort of "pan" or indurated condition of soil occurred. This pan may either be the consequence of the long-continued passage of implements and horses over the land during years of shallow cultivation; or it may consist of calcareous and gravelly matter, compacted together so as to prevent the passage of either water or plant-roots; or it may be what is well known as "moor-band-pan," an ochreous or ferruginous deposit, which binds the earthy materials, such as gravel and sand, into a compact concretion. Where land is thus affected the drainage is defective, the soil is alternately "ankle deep" and sun-scorched; and the crops, although promising in their early stages, fail as they approach maturity.

In such cases a strong subsoiler, drawn by four horses, is a most valuable means of improvement. Clay soils, on the other hand, although temporarily improved by the passage of the subsoiler through them, very shortly relapse into their former condition, and all traces of the work disappear. The Marquis of Tweeddale has improved an extensive tract of poor, high-lying soil in Haddington, known as the Yester Estate, by thorough drainage, followed by the use of what he has named the "subsoil-trench plough." This implement consists in the first place of a subsoiler or coulter of iron, which, as it passes through the subsoil, breaks and opens it. Immediately behind this coulter is an inclined plane or platform, which receives the subsoil, and, as it passes backwards, delivers it at a higher level among the surface-soil. The advantages claimed for these operations are an increased depth of soil, greater facility for the escape of water through drains, and greater ability to withstand severe droughts.

General Cultivation.—After land has been drained, and otherwise brought into a state in which it can be profitably farmed, it must be properly cultivated. The foregoing operations, when once well done, are to a great extent permanent. Cultivation, on the other hand, is a constantly recurring work. The object of all cultivation may be said to be twofold: first, to bring the land into a proper tilth for the contemplated crop; and secondly, as a means of destroying vegetable and animal pests. It is not our intention to enter into details respecting ploughing, harrowing, "cultivating," and rolling, but rather to lay down the principles which, if properly carried out, will lead to "clean" land and a good state of tilth. First, then, in dealing with land, we must endeavour to act in concert with Nature, rather than in opposition to her. Atmospheric influences are of an importance which cannot well be overated, and hence the need of autumn cultivation, by which land is exposed to the greatest changes in temperature. The most thorough cultivation is required during the period of "fallowing." This occurs at intervals of from three to seven years, according to the character of the soil, and it is then that the land is thoroughly cleansed from weeds, and brought to the finest possible tilth. The precise conditions which the farmer wishes to induce will depend upon the kind of fallow it is proposed to make. Where a "bare fallow" is necessary, a rough condition of soil throughout the summer is desirable, that weeds may be destroyed by the scorching sun of June and July. This condition of land is best obtained by spring ploughing. Where a root-crop is desired, the object is to obtain a fine tilth, to render the land clean, and at the same time to retain the moisture in the soil for the use of the root-crop. In this case, spring ploughing and spring working is scarcely desirable. By autumn cultivation is meant, first shallow ploughing (or paring of the stubbles immediately after harvest, so as to detach the weeds from the deeper layers of soil), harrowing and rolling, and afterwards collecting and burning the weeds in heaps over the field. The ashes are then spread, manure is carted on to and spread over the land, and the field is then ploughed deeply and left until spring, when it will be found in a finely-pulverised condition, owing to exposure throughout the winter. Ploughing such land again in the spring should be avoided if possible, and the less cultivation used at that time the better will be the prospect of a root-crop. By this means a fine surface and a moist condition of soil are both secured. Exceptional treatment is, however, so often necessary that we must be on our guard in accepting any prescribed course of cultivation, and remember that where every field has its own peculiar soil, and every season its own eccentricities, it is impossible to frame rules for action. Autumn cultivation is, however, always safe, and should be followed out as extensively as possible. Its advantages may be summed up as follows:—It ensures the beneficial action of the frost upon the land; it destroys the larvæ and eggs of insects and seeds of weeds; it conserves moisture in the soil. Where steam cultivation has been introduced, all these advantages are most perfectly realised. Clay lands are ever the most difficult to deal with, and up to this time the expense attending their cultivation, together with their want of adaptability for growing root-crops, has caused them to be less sought after than light lands. Steam cultivation is, however, destined to develop the resources of these soils in a remarkable degree. Clay lands require to be worked with much judgment. They should be worked dry; their tenacious character must be modified by applications of lime, by burning, by good dressings of farm-yard manure, and by avoiding meddling at improper seasons. They must also be cropped with wheat, beans, and clover; and the fallow portion must frequently be worked without a crop. When fallow crops are grown, they must be removed from the land before wet weather sets in during autumn. The cultivation of light land is easier than that of clays. These soils require compression rather than lightening up. Thus we find sheep are fed upon root-crop in the winter for the purpose of consolidating the soil. The light-land farmer is always insisting upon the importance of having his land "firm," while the clay-land farmer endeavours to counteract the heaviness and retentiveness of his land. Such is a brief statement of the means at our disposal for improving the texture of clay soils; it yet remains for us to consider how they may be enriched by the addition of fertilising materials. Further information upon the points touched upon in this chapter will be found in "Morton's Cyclopædia of Agriculture" (Blackie and Son), and the "Journals of the Royal Agricultural Society" (John Murray).

THE STEAM-ENGINE.—X.

By J. M. Wigner, B.A.

VERTICAL ENGINES—COUNTER—MARINE ENGINES—PADDLES—SCREW—GOVERNORS—DIRECT-ACTING, TRUNK, AND SIDE-LEVER ENGINES—HYDRAULIC PROPELLER.

Horizontal engines can be fitted with a condenser as easily as those which have a beam; but this is not very frequently done: as a general rule, they are of the non-condensing class. There is an almost endless variety in the form given to these engines, but the action of all is very similar to that of the one we have already described.

There is, however, one modification which we must just notice in passing, and which is known as the "oscillating engine." In this form the cylinder is mounted so as to vibrate on an axis situated at its lower end, or else at the centre as in the figure. The guides which control the piston-rod and the connecting-rod are here entirely dispensed with, and the piston-rod is connected directly to the crank, so that as it moves up and down the whole cylinder vibrates from side to side, and thus all strain on the rod is avoided. Fig. 38 will render this quite clear.

The steam-pipe is so arranged that it enters at the axis, and the valves are moved in the usual way by an eccentric. In an engine of this kind the greatest simplicity is attained, and the number of working parts is reduced to a minimum, but it has never been very generally used as a land engine. In steam-vessels, however, the principle has been carried out very successfully, as will be shortly explained.

There is one other useful appendage to an engine which we must just describe here. This is known as the "counter," or engine clock. Very frequently it is important to know the rate at which an engine is working—that is, the number of strokes per minute it is making. The "counter" accomplishes this. It consists of a dial with suitable attachments, and is so made that it registers the number of strokes or revolutions made since it was set, and thus we can at once tell the number it is making per minute or per hour.

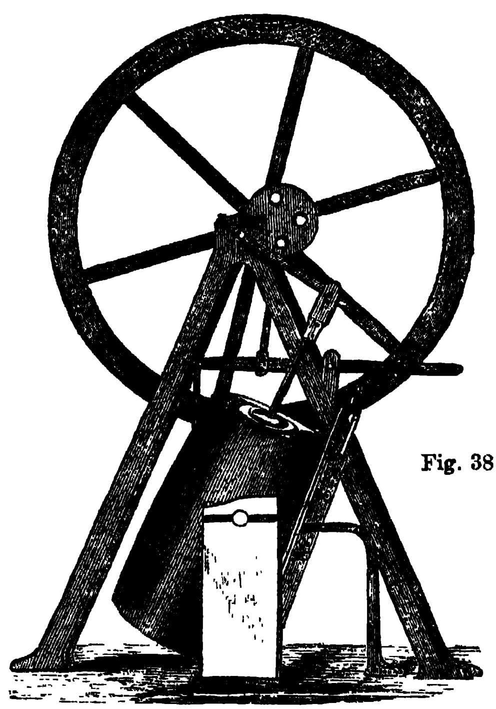


Fig. 38.

Soon after the steam-engine had begun to be at all generally adopted, attention was directed to the discovery of the best manner of rendering it available for purposes of navigation. Great practical inconvenience had long been caused by the dependence of vessels on the influences of wind and tide, and, even before steam was suggested, various mechanical contrivances, set in motion by the power of man or of horses, had been devised for the purpose of propelling vessels.

The most plausible of these consisted of a wheel carrying a number of floats round its circumference, after the plan of our paddle-wheels. About the year 1788, a Mr. Miller appears to have constructed a small vessel of this class, and to have driven the paddles by means of a steam-engine. It was only a small vessel, and was used for experimental purposes on a lake in his grounds; but the attempt was so far successful, that various modifications and improvements were soon made by other inventors, among whom the most prominent were Taylor, Symington, Fulton, and Bell.

We must not, however, pursue the history of the marine engine, interesting though it be to trace its gradual development; nor can we, in a brief series of papers like the present, inquire fully into all the details of the construction of marine engines generally, more especially as we should find that almost every maker has some special form or peculiar construction which he considers the best. All that we can do is as briefly as possible to refer to the principal points in which they differ from other engines. It is clear, in the first place, that since the engine has to be carried on board a vessel, in which as much room as possible is required for the accommodation of passengers and cargo, it must itself occupy as little space as possible, and also must be as light in its construction as it can be, consistently with having sufficient strength. For the same reason, too, the whole must be so arranged as to consume as little coal as possible. As a general rule, the vessel on starting must carry the greater part, or the whole, of the coal she will require during her voyage, since there are not many foreign stations where it can easily be procured, and even at these a greatly enhanced price has to be paid for it, usually three or four times the price that would have to be paid in this country. When we remember that in many large vessels the consumption may amount to thirty or forty tons a day, and that often they have to run very considerable distances without stopping, or without any opportunity of coaling, it will easily be seen how important it is that the amount consumed, as compared with the work performed, should be reduced to a minimum. The actual amount consumed increases greatly with the speed, and hence in the navy, on occasions where there is little need of dispatch, a great saving may be effected; in the merchant service speed is generally required, as more voyages may be thus accomplished the same time.

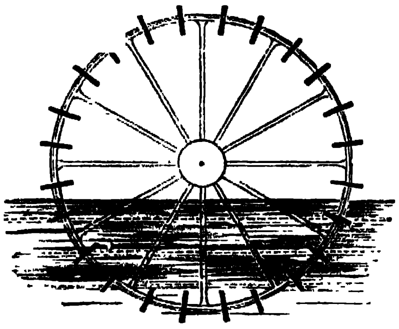


Fig. 39.

From their greater economy in fuel and other causes, low-pressure or condensing engines are almost exclusively employed in this country. Several boiler explosions, too, have occurred with high-pressure engines, and this has tended to strengthen the feeling against them.

There are two modes by which the power of the steam-engine is usually made to impart motion to the vessel. These are by means of paddle-wheels or by a screw-propeller. The former plan was first introduced, and was for a long time exclusively employed, but it is now rapidly giving way to the screw. In it a large and strong shaft passes from side to side of the vessel near the centre, and on each end of this a paddle-wheel is firmly secured. This consists usually of two or three metal rings, with paddle-boards or floats fixed to them. As the wheel rotates, these act on the water like oars, and thus propel the vessel. In Fig. 39 such a wheel is represented in section, and several dotted lines are drawn across it to represent different depths to which it may be immersed in the water; by observing the different angles at which the floats strike these, we shall easily see what an important thing it is to allow them to dip the right distance below the water. If the wheel be too deep, as it is in the figure, much power is consumed in moving the floats through the water, and, as will be seen, they oppose one another to a certain extent; if it be too high, they get but little hold.

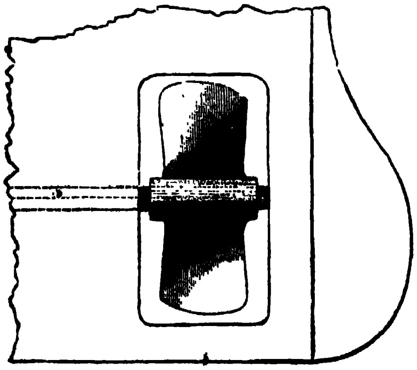


Fig. 40.

Now when a vessel leaves the docks to start on her voyage, she is usually somewhat deeply immersed, and hence the paddles do not act as well as they might. As the voyage progresses, some of the coal is consumed, and thus the vessel rises higher and higher out of the water. In some cases there will be a difference of three feet, from this cause, between the draught of water on leaving the port and on arriving out. It is clear, therefore, that the paddles must be adjusted for the medium displacement; but still there is a loss of power, and this is a considerable drawback to the employment of this mode of propulsion.

To obviate this in a measure, "feathering paddles" have been introduced. In these, each float, instead of being fixed to the wheel, is mounted so as to turn on a pivot. An eccentric is then fixed to the end of the shaft, and from this rods lead to the floats, and thus cause them to enter the water almost vertical, and to remain so as they pass through it. A considerable saving of power is thus effected, but the wheels are much more liable to get out of repair, besides being very greatly increased in weight and in cost, and hence they are not generally adopted.

In screw steamers the shaft runs lengthwise along the vessel, and the screw is placed at the stern, in an opening between it and the rudder-post. Much of the efficiency of the screw as a propeller depends upon the lines of the vessel. In several of the early experiments, the stern of the vessel was not suitably moulded, and, as a result, the performance of the screw was greatly inferior to the anticipations which had been formed. An idea of the construction of a screw may easily be formed by imagining a thin plate of metal on its edge, wound round a small spindle, or by supposing the thread of an ordinary screw extended outwards from the centre. By the pitch of the screw is meant the length of spindle in which the thread completes one revolution. In many screws the pitch is great, and then two or three threads, parallel to one another, are used.

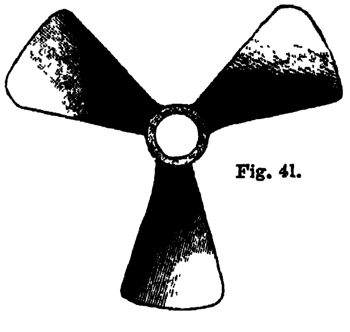


Fig. 41.

If we have such a screw with three threads, and cut off it a slice so thick as to contain about one-sixth part of a full turn, the piece cut off will clearly have three blades or arms projecting from it, each of which will be twisted partly round, as shown in Fig. 41. Each of these cuts the water as it revolves, and thus pushes forward the vessel just as a screw would if its nut were fixed while it revolved. At first a much longer screw was used, but it is now found that a short portion will answer as effectually. The usual plan is to make the pitch of the screw about eight or ten feet; sometimes, however, it is considerably greater than this. There exists, however, an immense diversity in the forms given to the screw, and in the number of blades; the general number is either two or three, but sometimes there are four, and in Captain Ericsson's propeller there are six, but these are fixed on a short cylinder connected with the shaft by three or more arms. Many vessels are now fitted with twin screws, one being placed on each side of the rudder.

Whether, then, the vessel is propelled by a screw or by paddles, we have in either case a horizontal shaft which has to be driven by the engine, and the engine must be so arranged as to impart a regular movement to this. One difficulty, especially in the case of a screw steamer, is caused by the necessity for the shaft to be low down in the vessel, since the screw should be completely submerged even when the vessel is light.

Then, too, a fly-wheel is inadmissible both on account of the space it occupies, and of the irregular motion of the vessel. This difficulty is usually met by employing two or three engines, so arranged that when one is at its "dead point" the others shall be working fully, and thus a nearly uniform motion is secured.

In a rough sea, however, there are very great fluctuations in the strain on the engine; at one moment the propeller is deeply immersed, and then again it is lifted quite out of the water. This causes the engine to "race" considerably, and a man is sometimes stationed by the throttle-valve to move it by hand, and prevent this as far as possible. Various kinds of governors have been tried with the same object, the ordinary balls being clearly unsuited, as the motion of the vessel would interfere with their action.

"Silver's momentum governor" is that most generally employed, and it is found to answer well. It consists of a small but heavy fly-wheel set in motion by the engine, the driving power being transmitted to it by means of a spring. The wheel moves at a considerable speed, so that its rate of movement is not easily altered, much power being stored up in it. Now if the rate of the engine be suddenly increased, the governor tries to maintain its own speed, and in so doing acts by means of the spring on the throttle-valve, and partially closes it. In a similar way a decrease in speed opens the valve, and thus a nearly uniform rate is maintained.

The shafts which move the screw or paddles have a very great strain on them, and must therefore be carefully made and tested; even then, however, they often crack after a few years' use. The iron appears to undergo a change by the continued jar, and to become brittle. Steel shafts have been tried, but have not been generally approved of, as they often break without giving any signs of warning, while in the case of wrought-iron shafts a small flaw usually appears first, and thus allows a sufficient space of time to prepare a new shaft, or to change the old one.

In a screw vessel the propelling power is at the stern, and thus the vessel is moved onwards entirely by the thrust of the shaft, and suitable arrangements have to be made to withstand this. Sometimes a thrust-block of steel, securely fixed to the engine, is placed at the fore-end of the shaft; but the more common plan is to employ a "collared bearing." In this the axle at one of the bearings, instead of being plain, is cut into six or eight deep square grooves, and corresponding grooves are cut in the block, which thus takes the strain. The friction in this case is of course very great, and much care is required to prevent the bearing becoming unduly heated.

The bearing where the shaft passes out of the vessel, at the stern, is usually lined with pieces of lignum vitæ or some other hard wood, and the little water which leaks through lubricates it and keeps all cool.

There are great varieties in marine engines, but most may be arranged in two or three classes. The first of these are known as "direct-acting" engines; in these the piston-rod is joined to the connecting-rod, and thus acts directly on the crank without the intervention of any side levers or other similar contrivances. In this way a considerable saving of room is effected, and the machinery is rendered less cumbrous and complicated; but there is the disadvantage that the stroke must of necessity be somewhat short, and the connecting-rod likewise is short, so that there is much additional wear and strain. Some plan, too, has to be devised for making the piston-rod move in a straight line, as the strain on it from the short connecting-rod is very great. This is sometimes effected by means of a series of jointed rods which form a "parallel motion;" in other cases a cross-head is attached to the piston-rod, and is made to slide between fixed guides which keep it in its place; while in other engines, again, the cylinder itself is made to oscillate on trunnions fixed near its centre, the steam being allowed to enter through these. The piston-rod is then connected direct to the crank.

It is by no means uncommon for two of these plans to be combined, and thus we sometimes see steamers in which there are three cylinders, the outer ones being fixed, while the centre one is made to oscillate; nor is it unusual for the fixed cylinder to be inclined or inverted so as to act more readily on the shaft. The variety is in fact so great, that scarcely any two engines are built on the same model.

There was at first some difficulty in imparting a sufficiently rapid rotation to the screw-shaft, and the plan was introduced of multiplying the speed by means of toothed gearing. In this form a large wheel is put in motion by the engines, and the teeth of this work in those of a smaller one on the crank-shaft, and thus the speed is largely increased. This plan answers much better than might be expected, and when the teeth are made of hard wood and well-shaped, there is little wear, and they work very steadily. It was, however, soon found that the speed of the piston might be safely and easily increased, and at the same time the stroke might be shortened; and hence "geared" engines are going out of use, and in nearly all cases the motion is now imparted direct to the shaft.

Another kind of engine, frequently employed, is known as the "trunk engine," and this is one of the most compact forms made, since in it the piston-rod and parallel motion are rendered unnecessary. A hollow trunk or cylinder is fixed to the upper face of the piston, and is made to work steam-tight through a stuffing-box in the cylinder cover. Sometimes, to impart additional strength and to equalise the strain, this trunk is continued below the piston, and made to pass through another stuffing-box in the lower end of the cylinder. The connecting-rod is then fixed to the top of the piston inside this tube, which is of sufficient dimensions to allow room enough for the rod to oscillate in it from side to side as the crank revolves. The annexed sketch (Fig. 42) will render this clear.

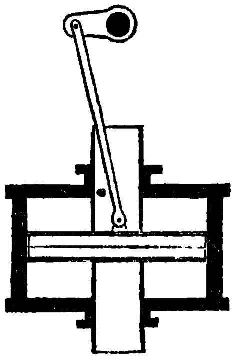


Fig. 42.

It will at once be seen that in an engine of this description the effective area of the piston is diminished by the space occupied by the trunk, but this loss may easily be compensated for by slightly enlarging the cylinders. When these are placed horizontally, as is often the case, all the machinery can be placed well below the water-line, and this, especially in the case of vessels of war, is a very important thing, since a shot will seldom penetrate a vessel far below this level.

The engines originally adopted for use on ships were a modification of the beam engine, already described, and are known as side levers. In these, instead of an overhead beam, one was placed at each side of the cylinder. These were connected at one end to a cross-head fixed to the piston-rod, and kept vertical by guide-rods or a parallel motion; and at the other end, to the connecting-rod which imparted the motion to the crank-shaft, as Fig. 43 will show. The benefits of this plan were that a much longer connecting-rod could be employed, and thus the movement was transmitted more evenly, and also that the parts were well balanced; but direct-acting engines save so much in space and in weight, that they are fast superseding these.

There are a few special features common to nearly all marine engines, to which we must now refer. On board ship the utmost care has to be taken to guard against fire, and hence in the boilers the furnaces and flues are always entirely internal, being surrounded in every direction by a layer of water. They are usually made sufficiently large to allow a boy to enter and clear out any deposit, as this would injure the plates if allowed to accumulate against them. The flues should also be so arranged that the steam, when generated, can easily rise. If it remains long in contact with the plates, it keeps the water from them, and thus allows them to become unduly heated.

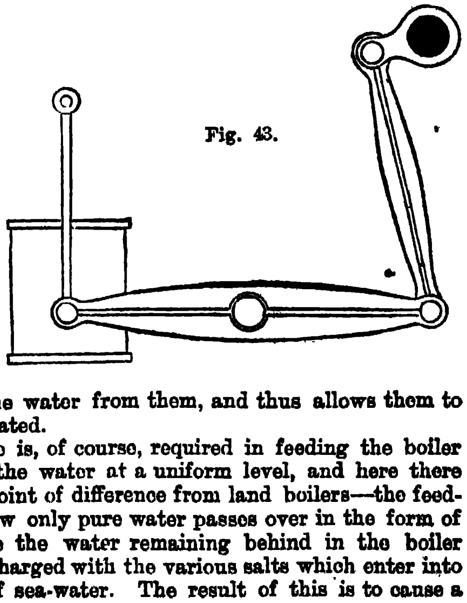


Fig. 43.

The utmost care is, of course, required in feeding the boiler so as to maintain the water at a uniform level, and here there is an important point of difference from land boilers—the feed-water is salt. Now only pure water passes over in the form of steam, and hence the water remaining behind in the boiler rapidly becomes charged with the various salts which enter into the composition of sea-water. The result of this is to cause a thick deposit of scale on the boiler, and at the same time to corrode the plates. This difficulty is usually overcome by blowing off into the sea a certain portion of the contents of the boiler, and thus getting rid of the excess of salt, and maintaining the water at a proper density. The engineer in charge must frequently test the water in the boiler, to make sure that this is properly done. As a general rule, from a quarter to a half of the amount of water supplied to the boiler has to be "blown off" in this way, and the best plan is to have a special cock provided for the purpose, and capable of exact adjustment. This should be kept continually open to such an extent as to allow a constant stream to escape, sufficient in quantity to keep the water at a suitable degree of saturation.

It is best to take the blow-off water from the surface, as various particles of "scale" and other impurities are carried there by the ebullition. A large shallow pan is therefore placed a few inches below the surface of the water, and the blow-off leads from the centre of this.

There is manifestly a very considerable loss of heat by this plan, and to obviate this to a certain extent surface condensers are now generally adopted. In these the condensing water is not allowed to mingle with the steam, but is made to pass through a series of pipes on the surface of which the steam is condensed. In this way the condensed water is perfectly fresh, and the boiler is fed with this, so that the same water is used over and over again. This plan alone will not answer, however, as a portion of the steam escapes and is lost, and besides this, the water soon becomes so foul from the grease used, and the particles worn off the bearings and other parts, that it corrodes the plates to a great extent, and causes the engine to "prime" very much.

The best plan appears to be to work the boiler at first with salt water till a thin scale has formed, which serves to protect the plates. The boiler is then fed more from the condenser, and less from the sea; but a certain portion of sea-water is always used so as to keep the water clean, and to maintain the density in the boiler about equal to that of the sea. The less oil or tallow is used, the better. In this way there is a much less amount of "blowing-off" requisite, and the boilers are kept in good condition.

Whichever form of condenser is adopted, it is very desirable to make arrangements by which it can, if necessary, be fed from the bilge of the vessel instead of from the sea. In this way a leak in a vessel may often be kept under, and large ships have sometimes been thus saved.

In engines used in river steamers the mud with which the water of the stream is frequently impregnated is sometimes a source of difficulty and disaster. Thus in the large and powerful steamboats which run on the Mississippi the quantity of mud held in suspension in the water of this river below the mouth of the Missouri frequently causes an explosion in the boilers by accumulating in a thick stratum at the bottom, as the salt accumulates in a marine boiler. The only remedy is to blow the water out of the boiler from time to time. This, however, is frequently neglected, and has caused many of the terrible steamboat accidents that have occurred on the American rivers.

Before passing from the subject of marine engines, we must just refer to an entirely novel kind of propeller recently introduced, and tried in H.M.S. *Waterwitch*, which was launched in 1866. In this there are neither screws nor paddles, the propelling force being entirely derived from the reaction produced by two large jets of water, thrown from nozzles placed at her sides a little below the water-line.

In the centre of the vessel is a large horizontal turbine fourteen feet in diameter, fitted with twelve blades. This draws the water from the sea, and forces it into a large chamber, whence it passes along rectangular pipes to the nozzles. Of these there are four, two pointing forwards and two aft, and the water may be made to issue from either pair at pleasure, and thus propel the vessel in either direction, a rudder being placed at each end. The vessel was tried and compared with the *Vixen* and the *Viper*, two vessels nearly similar in size and make, but fitted with screw-propellers, and the result was very satisfactory. The speed attained by the *Waterwitch* was about midway between that of the other two vessels, being about 9¼ knots.

In turning about, however, the other vessels, which were fitted with twin screws, had the advantage; but this could probably be easily remedied by altering the nozzles, so that they could eject the water at an angle instead of merely in the direction of the vessel's length. This plan has not, however, been adopted in many other vessels.

SANITARY ENGINEERING.—III.

PHOTOMETRY, OR THE MEASUREMENT OF GAS AND OTHER LIGHT.

In two previous papers we have dealt with the subjects of the "Manufacture of Gas by Public Companies," and "Gas-burners and the Economy of Gas Consumption:" we are now going a step further in the same direction, and shall endeavour to explain how gas-light is measured, how one burner can be compared with another, and also how the comparative lighting powers of different samples of gas can be ascertained and defined. This is done by means of an instrument called a photometer, or light-measurer, which consists of a long rod—five feet is not an uncommon length—carefully graduated from end to end, and fixed in a perfectly horizontal position; at either end of the rod, at adjusted foci, are the means of fixing either sperm candles (for a reason hereafter to be explained) or various descriptions of gas-burners—arrangements, of course, being made by means of flexible tubes or otherwise for the laying on of the gas—and the operation of the machine is as under. The experiments must be conducted in a dark room, from which every ray of natural or artificial light is carefully excluded, with the exception of the lights which are the subject of investigation—*i.e.*, which have to be measured. Backwards and forwards along the rod with its fixed light at either end a small metallic frame travels which carries a screen, a few inches square, of paper, one portion of which is saturated with oil so as to render it translucent, while the other portion remains in its natural state. When the screen is close to the light at the one end, the shadow thrown by the opaque portion of the paper is distinctly visible on the side opposite to the light; and when moved along the side to the other end, the converse result is obtained. At some given point between the two lights there is no shadow thrown either way, the power of the two lights balancing each other; the position of the screen on the graduated scale indicates the comparative power or measurement of the light.

Now as to the way in which this is practically applied. The *unit* of calculation adopted in practice is a sperm candle one-sixth of a pound in weight and burning 120 grains per hour; this is called a "standard candle," and the "standard burner" in use in London is Sugg's London argand, Number 1, which will indicate by the photometer a light varying with the quality of gas—of, say, from 13 to 17 candles. We mention these figures, not as the extreme which can be reached, for cannel gas of superior quality will give a much higher result, as we shall show by some figures in the sequel; but as pretty well including all the ordinary qualities of common coal gas likely to be supplied for household purposes, and showing the way in which legislation is brought to bear upon the subject, to protect the public and give some guarantee as to the quality of the gas supplied—a necessary precaution, gas being, more especially in county districts, almost a monopoly from the mere necessity of the case. We give an extract from one of the half-yearly "instructions" issued by the metropolitan gas referees to their examiners:—

"The burner to be used for testing the common gas of the Gas-light and Coke Company (which is required to have an illuminating power of 16 candles) shall be Sugg's London argand, Number 1, with a 6″ × 2″ chimney; and for the gas of the Imperial Gas Company and the South Metropolitan Gas Company (which is required to have an illuminating power of 14 candles) Sugg's London argand, Number 1, with a 6″ × 1¾″ chimney. If at any time the gas flame tails over the top of the chimney, a 7″ × 2″ chimney shall be used for the 16-candle gas, and a 6″ × 2″ chimney for the 14-candle gas.'

It is evident that the power of comparison thus obtained by the photometer may be applied to the comparison of larger or smaller burners, either with the standard candle or with each other, and it will thus be evident that the figures we may quote will not be in any way hypothetical, but all founded upon the basis of actual experiment. The popular way of describing the quality of gas is also thus explained: 14 or 16-candle gas, as the case may be, indicating the amount of light given by the gas when burned from a standard burner and compared with standard candles.

A curious and handy little experiment may be tried with common fish-tail burners:—Let a small size Number 3 fish-tail be fixed to the photometer *in situ*, and when all is arranged let the light be suddenly blown out; when the burner is sufficiently cool, place upon the top of it, where, as it is carefully turned, it will easily stand, another fish-tail burner of larger size, and then, turning on the gas, light the upper burner. Although the tube and pressure and every circumstance remain exactly the same, the photometer will indicate a most remarkable increase in the quantity of light—double in some cases or more according to the size of the upper burner.

Having described in general terms the working of the photometer, we may here note various points to be attended to in order to secure an accurate result.

The length of the chimney used with the burner is of great importance; by varying this even one or two inches 16-candle gas may give the effect of only 14, and *vice versâ*. The weight and quality of the candle must be most accurately ascertained. It is not uncommon to obtain varying results from different parts, even of the same candle, from slight variations of density only; even a perceptible per-centage of difference has been observed from a difference in the manufacture of the wicks—plaited, strongly twisted, or otherwise. The pressure of the gas also must be absolutely uniform, as an increase or diminution will produce an immediate variation of light. And lastly, the observation being conducted by the human eye, the difference of the power of vision possessed by various experimenters has a marked effect on the records.

All these points have, however, been carefully considered by scientific men, and a photometric apparatus has been designed in which every possible precaution has been taken to ensure accuracy. In some instances three or more arms duly graduated have been affixed to a central light, which is provided with an automatic apparatus for weighing the candle both before and after the experiment, conducted by a timepiece recording each second accurately by a dead-beat arrangement, the various operators, one to each arm, thus having a mutual check upon the results obtained.

When we consider the magnitude of the interests involved, the tens of thousands, nay, hundreds of thousands of pounds expended per annum in gas, and that by Act of Parliament, where in force, the companies are bound to produce gas of a certain quality, it is evident that it is of the greatest importance to obtain an unquestionably correct result.

Gas legislation is immensely voluminous: we can only allude, as the basis of most proceedings under this head, to the "Sale of Gas Act" of 1859. But the operation of this act being only permissive, it has been adopted by the City of London, one or two counties, and a few towns and districts, about fifty in number; the quality of gas elsewhere being subject only to the conditions imposed on the private Acts under which the companies are constituted, and of these it may fairly be said that their name is Legion, and their stipulations infinitely various. Several amendments of this Act of 1859 have been before Parliament in successive sessions, but for all practical purposes it is still in force. Our limits, and the object of our paper, do not allow us to go into the question of its working machinery—*i.e.*, constituted authorities, method of adoption, which, as we have said, is permissive—appointment and duties of inspectors—all points exceedingly interesting to parties concerned.

Going further, the question of the quality of gas, and the methods of testing it, the operation of the photometer may be taken as mechanical only; but it is possible, by means of chemical analysis, to arrive at far more accurate results: as, however, the experiments necessary require scientific knowledge of a high class, and also expensive apparatus, we may content ourselves by indicating the impurities that may thus be discovered, and some of the means employed.

It is of paramount importance that no admixture of atmospheric air should be allowed. Samples of the gas to be tested are therefore collected by means of a mercury trough into small gas receivers called eudiometers, and submitted to various chemical combinations. For estimating the amount of carbonic acid, caustic potash may be employed, and subsequently of oxygen with pyrogallic acid, and by a sequence of delicate operations the proportions of light carburetted hydrogen, carbonic oxide, hydrogen, and nitrogen can be successively ascertained; these operations, however, being strictly within the domain of the laboratory, and though of great scientific importance, inaccessible for general practical purposes.

We will here give the results of some experiments conducted by gentlemen whose names are well known in connection with the subject as to the comparative illuminating power and cost of gas as burnt through different descriptions of burners, and also as compared with other methods of lighting.

1. Series of Experiments by Dr. Fyfe, comparing Different Burners.

Burner.	Consumption per hour.	Light given.	Illuminating power per foot of gas burnt.
Jet 5″ high . . .	1·0	1·0	1·0
Small fish-tail .	1·98	2·89	1·45
Large ditto . .	2·60	4·0	1·53
Small bat's-wing .	3·0	4·40	1·46
Large ditto . .	4·60	8·40	1·87
Argand of 40 holes .	4·50	7·84	1·74

These experiments were all made with cannel gas.

2. Experiments showing the Comparative Cost of Different Lighting Materials, the same Amount of Light being obtained in each case.

	s.	d.
Spermaceti candles	6	8
Paraffin ditto	3	10
Tallow ditto	2	8
Sperm oil	1	10
Gas	0′	4½

There is a popular impression sometimes prevalent that gas is unwholesome: the following table details experiments in which flames of equal power, photometrically ascertained, were placed in an exhausted receiver constructed for the purpose—the time at which the light became extinguished for want of oxygen giving a comparative figure from which some idea may be formed of their effect upon the atmosphere of an ordinary room:—

Cannel gas, 28 candle power,	burned for	152	minutes.
Coal gas, 13 candle power .	,,	98	,,
Spermaceti candles . . .	,,	83	,,
Wax candles	,,	79	,,
Sperm oil	,,	76	,,
Tallow	,,	75	,,
Colza oil	,,	71	,,

Cannel gas we have now alluded to almost for the first time. The quality of the coal from which it is made has the peculiar property of producing a gas of much greater illuminating power than ordinary commercial coal gas. A glance at the table last quoted will give some idea of its comparative purity; but at the same time it should be stated that the cost of its production is greater in almost a similar proportion. It has been sometimes used mixed in certain proportions with common gas with good results. In cases where private gas-works are erected it may be highly recommended for some special purpose—*e.g.*, for delicate manufactures, where the *quality* of the light is of more importance than its cost; also for situations where it is of importance that the products of combustion shall be as free as possible from deleterious elements. Picture galleries may be mentioned as an instance.

To burn it with advantage it requires special adaptations of burners and pressure different from those in ordinary use, as if consumed under the same conditions as ordinary coal gas a large proportion of its singularly powerful *lighting* qualities are wasted. Our space will not allow us to go into detail upon these points, which, indeed, are scarcely included within the range of domestic engineering, as, except for a factory, a large mansion in the country, or somewhat similarly extensive requirements, private gas-works are rarely required. In a subsequent paper, however, on the special subject of private gas-works, we shall probably give some idea of how its advantages can be made available, and of the various modifications of detail required for its profitable consumption.

At some future day we have no doubt that the progress of discovery and experiment will provide us with a gas made from petroleum, which in cleanliness of burning and lighting power will far exceed any gas at present in the market. This, however, is only a speculative notion. As a matter of business nothing of the kind has yet been developed to the point of commercial success, though the experiments made with this special end in view have been very numerous.

OPTICAL INSTRUMENTS.—VIII.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLE LENSES.

Their Form.—The lenses employed for correcting defective vision are of two types—the *converging*, which bring parallel rays to a focal point, and the *diverging*, which cause parallel rays to turn outwards from the axis of the lens.

The converging include the *bi-convex*, A (Fig. 15), the *plano-convex*, B, and the *concavo-convex* or *positive meniscus*, C (with shorter radius of the convex surface); the diverging, the *bi-concave*, D, the *plano-concave*, E, and the *convex-concave* or *negative meniscus*, F (with shorter radius of the concave surface). As the plano-convex and the plano-concave have, for equal degrees of power, the greatest aberration, they are least suited for spectacle glasses. To the menisci Wollaston attributed the advantage that the images suffer less when the observer looks obliquely (from the axis) through them, so that the eyes can move with a greater angular range behind such glasses, hence they are termed *periscopic* (from περισκοπειν, "to look around"); but Brewster, while allowing their value in a crowded city, in warning us of the oblique approach of objects, asserts that menisci decidedly give more imperfect vision than the ordinary form employed for spectacles, as they increase both the aberration of figure and colour.[*] Under certain conditions the periscopic form is liable to produce disturbance, by reflection on the concave surface turned towards the eye of the wearer. It is, therefore, on optical grounds, rather than from the fact that periscopic lenses are somewhat more expensive, that preference is usually given to bi-convex and bi-concave spectacle glasses. With these we can see satisfactorily in an oblique direction unless the power is very high; and when strong glasses are required the periscopic form entails the disadvantage of a greater weight of glass; so there is ample reason for not assenting to that unconditional preference for the periscopic lens which some surgeons and opticians profess.

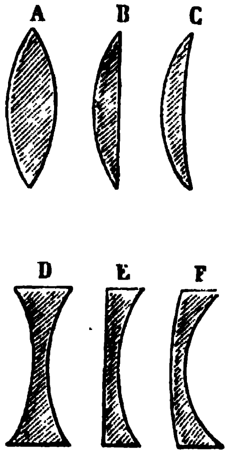


Fig. 15.

Material employed for Spectacle Glasses.—Rock-crystal and glass are the materials employed in the construction of spectacle lenses. The former is usually called by the trade pebble, or Brazilian pebble, being a natural crystal, the samples best suited for optical purposes being imported from the Brazils. As it is of equal density throughout its mass, very clear, extremely hard, takes a very high polish, and is cooler than glass, it is usually selected for the best class of spectacles, for it is important that spectacle lenses should be colourless, of equal transparency throughout, be free from striæ, blobs, etc., and have a high polish, which shall not be readily deteriorated by wear. Next in value as meeting these requirements is flint glass; but as crystal and flint glass possess a high dispersive power, crown glass, though softer and so much more liable to injury, is preferable for the construction of "strong glasses," especially of concave glasses. The cheapness of crown glass compensates for its deteriorating quality, for if spectacle lenses of this material become scratched through constant wiping or being laid carelessly about, their low price makes it easy for those of limited means to replace them. A glass dulled by fine scratches over its surface should be banished from its frame, as it tends to strain the sight of the wearer.

It is very important that the optician should be readily able to distinguish a pebble from a glass lens; also whether a pebble is of good optical character, or has been improperly cut. We may distinguish between the two, first, by determining the hardness, for rock-crystal, being considerably harder than glass, will scratch it; or by drawing the edge of the sample under trial briskly over a file it will emit sparks and not yield, while glass, on the contrary, will break down into fine powdery particles. Again, on applying samples of glass and pebble to the tongue, the latter will prove to be much colder than the other; the experienced will even detect this by the touch of the finger only. But these tests do not tell the optician all he wants to know, and the tourmaline polariscope gives the desired information in the simplest and readiest manner. This instrument consists of two thin slices of hair-brown tourmaline, cut parallel to the longer axis of the crystal, fitted in corks, and mounted in rotating tubes that face each other, which are supported by two spring blades, attached to a handle, in such a manner that a lens, etc., can be placed and held between the two pieces of tourmaline, as shown in Fig. 16. On rotating one of the crystals two positions will be found, one in which the colour of the tourmaline is apparent, with perfect transparency; the other when the crystals stand at right angles to this position, and the field of view is perfectly obscured. If now we introduce a lens of *glass* between the tourmalines (without disturbing their position), the field will still appear opaque, and *any glass lens* will give the same result,[*] and so indicate the characteristics of the material. If we now replace the glass with *a properly-made rock-crystal lens* the transparency of the field of view *will be restored*, but will be quite free from colour (the tint of the tourmalines allowed for); if, on testing other pebble lenses, prismatic tints, rings, or bands appear, we learn that the material is rock-crystal, but that it has not been cut with proper regard to the optical and crystallographic properties of rock-crystal (which will be hereafter described under Apparatus for the Polarisation of Light). Brazil pebbles are imported in rough blocks, but are really more or less defaced or water-worn crystals of the purest quartz. These are cut on a slitting-wheel, by the aid of diamond powder, into slabs or pieces of the size required; but if cut in other directions than parallel to the longer axis of the rock-crystal, tints of colour of greater or less intensity will appear in the lens; and if a slice were cut at right angles to the axis of the rock-crystal, a series of well-defined prismatically-coloured rings would appear in the lens, which would indicate its unfitness for a spectacle lens; for though these colours would not be apparent to the wearer, it would possess refractive properties that would tease the eyes, for pebble is a double refractive body, and if sliced in certain directions, through ignorance, carelessness, or indifference to conscientious workmanship, two objects instead of one are seen. Such lenses, together with those that possess wavy appearances, bubbles, or other defects, are technically called "*wasters*," and, unfortunately, are not unfrequently met with. No respectable optician would knowingly admit such refuse into his stock.

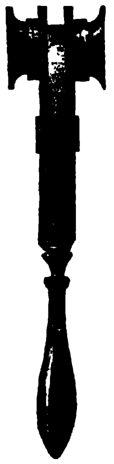


Fig. 16.

The process of working single and achromatic lenses will be described in a separate article.

As spectacle lenses are of universal and daily requirement, they are now, as a matter of necessity, nearly always produced in quantity by the aid of machinery; though, as a rule, preference is to be given to lenses carefully worked by hand, under the keen eye of a skilful workman, who brings brain and touch to detect all defects of form, centering, and polish.

To determine the Focal Length of Lenses.—It is essential that the optician should have a ready method for determining the focal length of lenses, not only of samples in stock, but of those brought by customers in their spectacle-frames, which they require to be matched or replaced with others of higher power. The usual method followed in the shops in regard to convex lenses is to throw the image of the window-frame formed by the lens on to a sheet of white paper placed against the wall in a dark corner, and then (after moving the lens to and fro till perfect definition of the window-bars is attained) to note with a rule the distance in inches between the paper and the lens.

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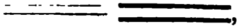
[*] The difference in definition between a periscopic and a convex lens (both being of equal focus and diameter) should be noted by projecting the image of a candle-flame on to a sheet of paper placed in a dark room, the two lenses being held edge to edge. The image from the periscopic lens will be surrounded by a dazzling halo.

[*] Unless it be purposely *unannealed*—a thing not likely to be met with in practice—in which case coloured rings, etc., would appear, intersected by a black cross. Such glass would be unfit for spectacle lenses.

Or the inverted image of a candle (placed at some feet distance from the wall) is noted in the same manner; or, better still, if it were not that it is not always available, the image of the sun, or, as it is termed, the *solar focus*, may be employed. But it must be observed that these methods only give the value approximately; and for the reason given in the foot-note at page 111, Vol. I., the object selected (whether window-frame, perforated zinc, or candle) should always be placed *at a fixed or standard distance from the lens under trial* of at least 18 feet, so as to deal with what are practically parallel rays. The image being then focussed on a screen that *moves away from the lens*, the intervening distance or focal length is measured by a tape or wooden scale. In communications between customer and optician as to a lens of a required focus, say to replace a broken glass and pair with the remaining one, the method followed for determining the focus and the distance of the window or candle from the wall (or lens) should be ascertained to avoid error, for it will be found that the focus obtained by using a near and then a distant object will not give identical results. As it is not always possible or convenient to obtain a range of from 18 to 20 feet for the method of testing just described, a simple and better method is to use as an object two lines ruled parallel on a sheet of paper, and then view this with the lens to be tested, held at about a foot distant from the eye, and so far from the paper that both lines can be accurately seen. We now place the standard trial-glasses of known focus in succession beside this, in the same plane, with the edges touching and the centres in a line, till we find the number that gives an image of equal magnitude. When the two lines appear continuous through both lenses, the number on the trial-glass will indicate the focal length of the lens under examination. On the other hand, should the lines appear disjointed, thus, , then the standard lens does not match the glass under trial, and another must be sought. By thus trying with what trial-glass a lens agrees in magnifying or diminishing power, we can determine the focal length not only of convexes but also of concaves. The most common method of ascertaining the focal length of concaves is to place them in contact with the surface of a convex lens that will best fit the concavity of one face. When this is accurately done the power of both lenses will be neutralised, for we convert the conjoined lenses into what is equivalent to a meniscus of equal curvatures; in which case, the two surfaces being parallel, all lenticular properties are wanting (see Fig. 15): and on holding them in contact between the finger and thumb, and moving them to and fro at some distance before the eye, an object seen through the pair will appear fixed, equal, and of the natural size, and the known focal length of the convex will give the value of the concave. Should the convex, however, not be of exactly the same focal value as the concave lens under trial, then the objects observed will appear to have a tremulous motion, or larger or smaller than they really are, and the proper neutralising lens must be sought. When we have no standard trial-glasses of known focus at hand wherewith to determine the power of a concave glass, we may ascertain its focal length approximately by treating it as a concave mirror. Reflect the image of a bright flame on to a sheet of white paper, and when well defined, measure the distance between the centre of the concave lens and the screen, and so obtain a direct reading. The focal lengths of convex and concave lenses may also be accurately and conveniently ascertained by Dollond's focimeter, for by this instrument we ensure a trial under conditions that are invariably the same.

Dollond's *focimeter*, as improved by Phelps, consists of a small telescope, specially adjusted for the purpose required, mounted on a long square bar of wood 5 feet in length; this is graduated up to 48 inches down the centre of the bar, the zero point of the scale corresponding with the plane of the object-glass. On one side a comparative scale corresponding to the French standard is engraved, on the other the Prussian scale; so that we can at once determine any discrepancies as to lenses that have come from foreign sources, and been marked accordingly in French or Prussian inches, or for use in supplying glasses ordered by surgeons who employ foreign trial-cases. Over the bar traverses a stage that carries the object to be focussed. The lens under trial, if a convex, is held immediately in front of the object-glass of the telescope with one hand, while the test-object is moved to and fro with the other till it is distinctly defined. The reading is then observed through a slot in the traversing stage that corresponds to the plane of the test-object.

When concave glasses are to be tried, a brass cap fitted with a correcting lens suited for focal lengths of from 1 to 8 inches is fitted in front of the object-glass. The concave is then tested in the same manner as previously described. Should it prove above 8 inches in focus, the correcting cap is replaced with another suited for a range of from 9 to 14 inches, which comprises the usual range employed in England.

At page 307, Vol. I., of THE TECHNICAL EDUCATOR I have enumerated the glasses supplied in the German trial-cases, and also the series usually furnished in the set of English "convex triers," viz., 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 24, 30, 36, 48, which numbers express the focal lengths of the convex lenses inserted in the frames. The set of English "concave triers" usually includes a series numbered from 1 to 14. Such numbers *should* indicate negative focal lengths corresponding to the positive focal lengths of the convex series, for it is the only standard that is scientifically correct and admitting of universal application, for the reason that while all double-convex lenses are worked *in* a concave tool, the curve of which has a radius equivalent to the focal length of the *double-convex* lens it produces, all concave lenses are worked *on* a convex tool, the curve of which also has a radius equivalent to the focal length of the *double-concave* it produces. Thus, a concave tool of 7 inches radius would be used to work the two surfaces of a double-convex lens of 7 inches focus, and a convex tool of 7 inches radius to work the two surfaces of a *double-concave* lens of 7 inches focus. By following this method of making the numbers in the trial-cases, and on the lenses supplied, represent the focal lengths of concave as well as convex lenses, we have a ready means of determining the focus of concaves as previously described, wherein the concave curves neutralise the convex curves, and reduce the combination of two lenses of the same foci to the optical value of a piece of glass with *parallel* faces, though the surfaces are curved, as shown in Fig. 15 B, and still more strikingly shown in Fig. 15 E, which represents a plano-convex and a plano-concave, *each* of 14 inches focal length, made from the same tools of 7 inches radii, wherein the perfect parallelism produced by the combination of the two lenses is palpable. Unfortunately, this simple system, the common-sense and scientific value of which is self-evident, has not always been followed; and the "shop element," in the interest of quack oculists, has led to the introduction of arbitrary numbers and scales, that could only have been adopted to "fog" those who were not in "the favoured circle." Thus, according to one arbitrary system (as a sample of many others), a concave *numbered* 1 corresponded to a 24-inch convex; No. 2 concave to a 21-inch convex; No. 3 concave to an 18-inch convex, and so on; instead of 24 concave = 24 convex, 22 concave = 22 convex, 18 concave = 18 convex, and so on. So that if a patient went to any other optican but that recommended by the oculist he would not obtain the glasses absolutely required. Again, I have before me an arbitrary scale of German invention that does not correspond to the standard of any nation.* It runs in the following fashion:—

Up to No. 7 it corresponds exactly inch for inch with the English scale; then—for convex numbers—

8	*nearly* corresponds	with our	8¼ inches.
9	„	„	9⅓
10	„	„	10½
12	„	„	13
14	„	„	13⅜
16	„	„	17
18	„	„	19
20	„	„	22
22	„	„	25
24	„	„	28
30	„	„	35
36	„	„	44⅓

No. 30 in this scale is the zero point for the concave series; and going upwards—

No. 1 = 24 of the German scale.
„ 2 = 20 „
„ 3 = 16 „
„ 4 = 14 „
„ 5 = 12 „
„ 6 = 10 „
„ 7 = 9 „

No. 8 = 8 of the German scale.
9 = 7 „ „ „
10 = 6 „ „ „
11 = 5 „ „ „
12 = 4½ „ „ „
13 = 4 „ „ „

I need hardly say that no respectable optician should countenance any such arbitrary or irregular scales, palpably devised for the purpose of "fogging" the uninitiated; and any "medical oculist" who adopted such a scale could not feel aggrieved if his claim to a scientific position were disputed, and he were branded with the title of "Quack," for no true disciple of Science would ever give countenance to mystery.

I must here give a caution as to the discrepancies which may arise from the use of trial-cases furnished from different countries, any errors arising from which source I hope to correct by placing before the readers of THE TECHNICAL EDUCATOR, in a future number, a comparative series of measures of all nations, which would possess great value for many scientific and artistic purposes. The optician should therefore always be particular to ascertain, when spectacles are ordered for a patient by an ophthalmic surgeon, whether he adopts an English, French, or German series of trial-glasses. Through this multiplicity of standards great confusion and annoyance has been caused both to opticians, patients, and surgeons. Undoubtedly, it would be an advantage for all scientific purposes if the French scale founded on the metre adopted by the Paris Board of Longitude were followed, as being the only standard established on a scientific basis, our own and all other measures of length, etc., being arbitrary.

SPECTACLE-FRAMES.

The Frames.—Formerly the spectacle lenses were supported in heavy frames of tortoiseshell, silver, or gold, but the two first are now seldom employed, tempered steel or gold having superseded such antiquities, shell-work being only used for eye-glasses and spring-folders. As there are many qualities of material used in the manufacture of blue steel spectacle-frames, varying from mere soft iron, or iron fronts with steel sides, to the very best quality wrought out of steel plate, particular attention should be given to the lightness and temper of the work, for it is well to remember that a pound of pig-iron, which costs but a penny, can be wrought into watch-springs of the value of £240! Some so-called steel frames will be found to bend like a piece of bottle-wire, but the genuine article will always keep its shape. Provincial-made frames are produced in quantity, and seldom possess that finished workmanship which characterises the best London-made spectacle-frames. The price of a frame, then, depends upon the quality of its material and the finish of its workmanship. In a well-made frame the side-pieces should turn out from the hinge as firm and straight as the blade of a well-made penknife would do from its handle, for any amount of play in the joint should only exist after long wear and tear; and there should be no perception of anything like a grating, rasping action when the side-piece is being worked backwards and forwards in its joint. Should the side be lengthened by a second piece, working on a "turn-pin," the two should fold neatly and closely together, and the turn-pin should hold them at any position in which they should be placed in relation to each other. When the side-pieces are turned down they should protect, not scratch against the glasses, which, when packed away, should be guarded on their exposed side by the concave form of the spectacle-case, especially for convexes, which are more palpably exposed to injury by scratching than the indented surfaces of concaves.

It is a mere matter of fancy or fashion whether steel frames are blue or "straw colour," either tint being produced at will in the process of tempering. The same may be said with regard to the shape of the lens-rims. Old-fashioned spectacles were made with "round eyes," but as we secure a sufficient range of observation with the modern oval-shaped glasses, without teasing the eye with the excess of light the antiquated round eyes admitted, the latter are now seldom employed but for exceptional purposes, for they are not only clumsier in appearance, but also entail a greater and unnecessary weight.

Next to the proper selection of the glasses it is a matter of the greatest importance that the frames should accurately fit the face of the wearer. And here I may observe that the majority of people fail to notice the importance of having such an important organ as the eye accurately measured and fitted; yet persons who would never dream of purchasing a pair of ready-made boots, or of putting on a suit of slop-shop clothes, do not hesitate about taking the first pair of spectacles that are given to them from the stores of jewellers, toy-merchants, and other dealers who dabble in optical goods; who, they must know, if they gave a moment's thought to the matter, have no pretensions to optical knowledge. Every optician must have met with a middle-aged housekeeper who has adopted a pair of her aged master's cast-off spectacles, or a needy clerk who has secured, as he thinks, "a great bargain" at a pawnbroker's, and both of these types wonder why their eyes are fatigued and the sight deteriorated since they began to wear such glasses.

The main points of construction are that one glass should not stand higher than the other; that the centre of each glass should coincide with the centre of each pupil (or otherwise they will act as prisms, and tend to create a squint), or but slightly less apart than the pupils for near-sighted spectacles; that the bridge or nose-piece should be flattened or arched out according to the shape of the wearer's nose and face, so as to allow of distinct vision for distant objects over the top edge of the frame, and for concaves being placed nearer to the eye than is necessary or advisable for convexes; that the sides should neither press the head too tightly or too lightly, but just secure a comfortable grasp; and that "the front" is not so short for the wearer's face that he looks upon the outer, or so long that he looks upon the inner edge of the glass or metal rim.

If we apply these rules to the ever-varying proportions of the human face, it may be gleaned that when an accurately-constructed pair of spectacles is desired, and a few days can be allowed to the optician, it is better to make them specially for each patient rather than take a frame from stock that nearest meets the desired requirements.

The mean distance between the centres of the pupils of the eyes is on an average about 2½ inches. The exact distance for each person may be measured by means of the points of a pair of compasses, guarded with two small black beads, adjusted till the points correspond to the centres of the pupils, while the person looks at a distant object to prevent squinting, which would give a deceptive gauge. The compass-points should be pressed on paper on which the patient's name, with all other details for constructing the frames, should be filled in.

The length of the bridge varies from 1 inch to $1\frac{3}{10}$ inches. The longer diameter of an oval rim should be about $1\frac{1}{10}$ inches, the shorter diameter about $\frac{9}{10}$ inch. The joint or knuckle varies from $\frac{2}{10}$ to $\frac{4}{10}$ inch.

I may here remark that the knack which some persons have of placing the bridge on the very tip of the nose should be discontinued, as injurious and absurd. On the other hand, pressing the glasses *too* close to the eyes may irritate and inflame the eyelids, or at least the glasses will be dimmed by moisture from frequent contact with the eyelashes. The front should be perfectly rigid, for if it yields the glasses lose their parallelism with the eyes, when vision will become disturbed and the sight distressed. The first joint or side-piece should be 4½ inches long, and so curved that only the last half-inch touches the head. The second joint or piece beyond the turn-pin should be 2¾ inches long. Whether one or two joints are employed, the ends should terminate in a loop, which is filled up with sealing-wax.

The glasses as sent out from the grinding tool are round, and they are clipped into an oval form of the exact size of the opening in the frames by means of a pair of flat-bladed nippers, which crunch off the superfluous glass bit by bit; and the edges are ground even, and smooth, and angular in a small grindstone, supported in a water-trough. The small screws in the knuckles are removed to facilitate the insertion of the lenses so edged. The proper centreing of the glasses in their frames is effected during the process of shaping with the nipping tool.

PRACTICAL PERSPECTIVE.—XI.

FIGS. 52, 53, 54, 55.—The subject of this lesson has already, in Fig. 28, occupied the attention of the student; but in the former case the table was placed so that one of its sides was on the picture-line, the length being parallel to the picture-plane: whilst in the present study the sides recede at certain angles.

Fig. 52 is the plan of the table placed at the required angles in relation to a straight line. Fig. 53 is the side elevation—that is, the exact geometrical figure which would stand on the line A C of the plan; the points which would correspond are similarly lettered. Fig. 54 is the end elevation, or that which would stand on the line A B.

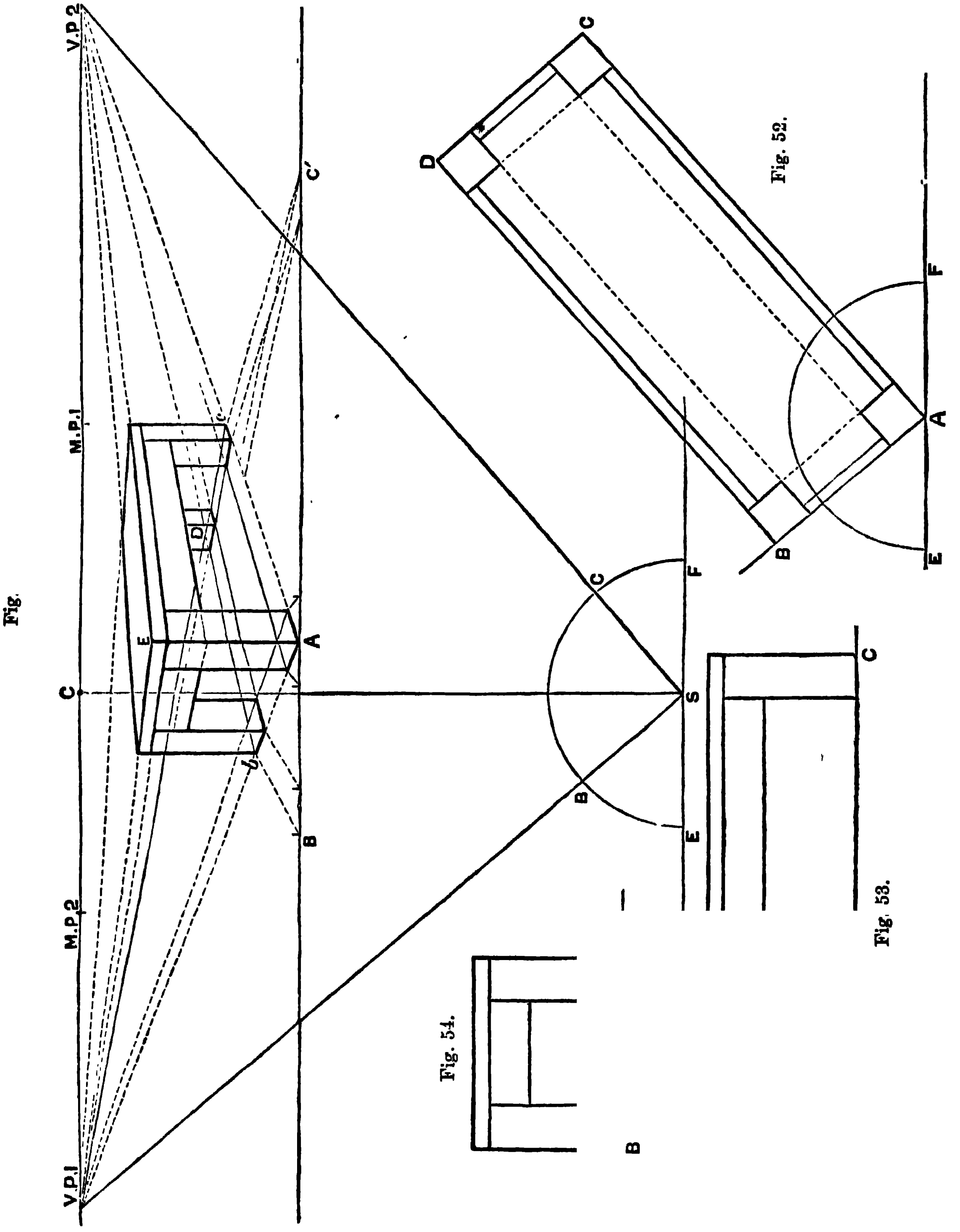


Fig.

Fig. 52.

Fig. 53.

Fig. 54.

We now proceed to work out the projection from these given data (Fig. 55).

Having drawn the picture-line, the horizontal line, and line of direction, find the vanishing-points—that is, construct at the station-point S, angles B S E and C S F, similar to the angles B A E and C A F in the plan. Produce these lines until they meet the horizontal line in VP1 and VP2, and from these points, as shown in former lessons, find the measuring-points.

Now from A on the picture-line, the point at which it is required that the nearest angle shall be situated, draw lines to the vanishing-points.

From A set off A B and A C' equal to the sides of the table, taken from the plan (Fig. 52).

From B and C' draw lines to the measuring-points, cutting A VP1 and A VP2 in *b* and *c*.

From *b* and *c* draw lines to the opposite vanishing-points, cutting each other in D, and this will complete the boundary of the plan.

On each side of A set off the thickness of the legs, measured from the plan or either of the elevations, and on the inner side of B and of C' set off the same width; and from each of these points, as before, draw lines—first to the measuring-points, and then to the vanishing-points; and these will complete the plan.

The height B having been marked on the perpendicular A, the rest of the figure will be worked as shown in several previous lessons.

Exercise 43.

Put into perspective the table shown in the last study, when it is placed at a given distance—say 10 feet within the picture, the height of the spectator in Fig. 55 being taken as 5 feet.

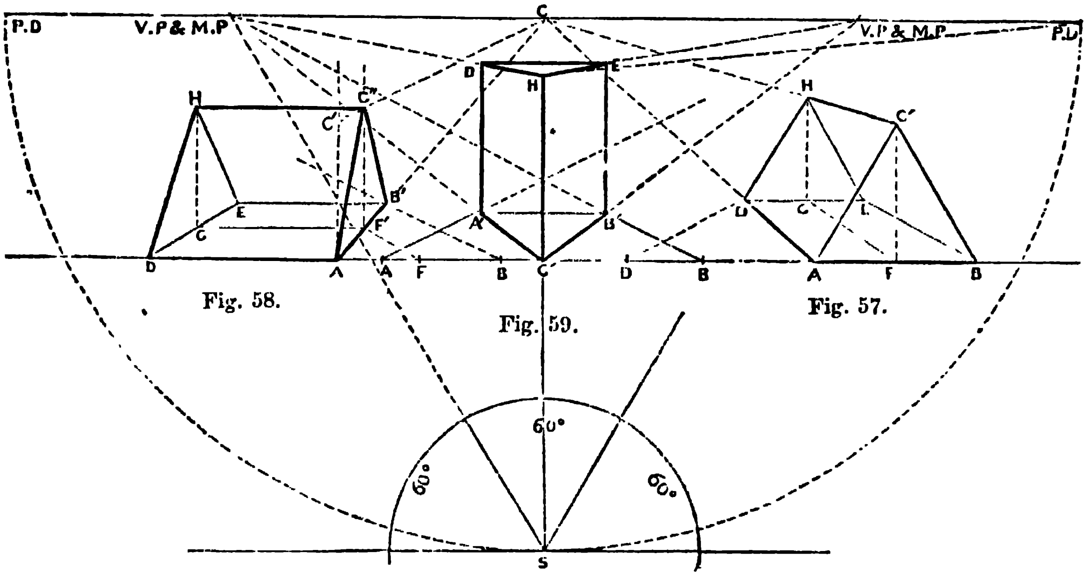


Fig. 58.

Fig. 59.

Fig. 57.

Fig. 56.—This study is a further development of the previous one, and shows a table the top of which projects beyond the plane of the legs and framing. Having drawn the preliminary lines—the plan and elevations of the object according to the system shown in the last study—and having found the vanishing-points and measuring-points according to the angles at which the sides of the object are supposed to recede, project the boundary of the plan. This done, set off from A, and also within the points on the picture-line from which the lines were drawn to the measuring-points, the widths, first of the projection of the top of the table beyond the plane of the legs, viz., B and C, and secondly, the thickness of the legs, viz., D and E.

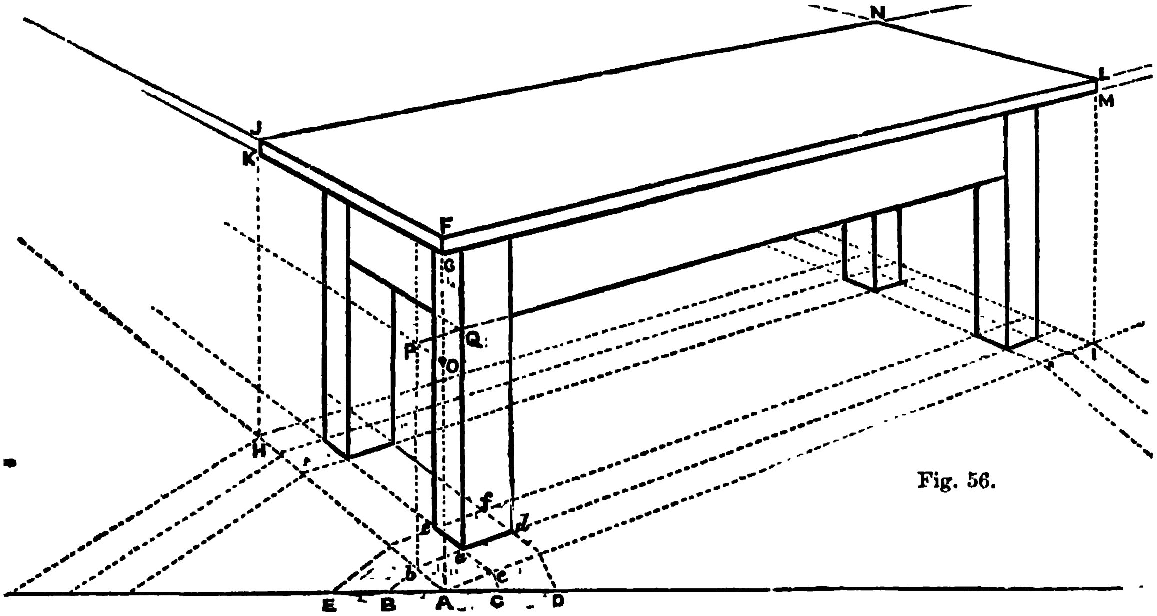


Fig. 56.

From all of these points draw lines, first to the measuring-points, and then to the vanishing-points. The process is, in fact, a repetition of the last figure, excepting that there is a double set of lines employed.

It will now be observed that whilst in the last study (Fig. 55) the front leg stood on the square corresponding with A *b a c* in the present figure, it is not so in this instance, for the legs stand back, although the angle of the top of the table would in reality touch the picture-plane. The leg, therefore, stands on the figure *a e f d*, and the other three legs stand upon the corresponding lozenge-formed figures in the angles of the inner figure.

Having completed the plan, draw a perpendicular at A, and on this mark the points F and G for the full height and the thickness of the top of the table; from both of these points draw lines to the vanishing-points (not shown in this figure).

From H and I, the two distant angles of the plan, draw perpendiculars, cutting the lines drawn from F and G to the vanishing-points in J K and L M; these will give the distant angles of the top of the table, for it will be clear that those will be exactly over the angles of the plan H and I, as F and G are immediately over the nearest angle A.

From J and L draw lines to the opposite vanishing-points, which, cutting each other in N, will complete the top of the table.

Now draw the perpendiculars *e*, *a*, and *d* for the nearest leg, and the *two* outer perpendiculars of the legs at H and I, leaving the third perpendicular of each of these, and also the whole of the distant fourth leg for the present.

It is now time that the framing under the plate of the table should be drawn. This is not on the same plane as the edge of the table, but forms in most cases a portion of the plane of the legs, whilst in others it is mortised so as to leave the legs a little more forward than the surface of the framing. For the sake of simplicity, the former case is assumed. It becomes necessary, therefore, in the first place to mark its true height in the foreground, and then carry it back.

On the perpendicular A mark the real height of the bottom line of the framing—viz., O; and from *b* erect a perpendicular.

Now from O draw a line to the vanishing-point, cutting the perpendicular *b* in P.

On examining the plan, it will be seen that *b* is on the same plane as the point *a*, and therefore the perpendiculars *b* and *a* are on the same plane; hence a line drawn from P to the same point to which the line from *b* is vanishing must pass through the perpendicular on *a* in the point Q, and this is then the perspective height of the framing.

From Q draw lines to the vanishing-points, and then the third perpendiculars of the legs, and the distant leg, may be drawn, thus completing the object.

EXERCISE 44.

The height of the table in Fig. 56 being taken at 2 feet 6 inches, put the same object into perspective when standing at the same angle as in the last study, but at 6 feet within the picture.

EXERCISE 45.

Put into perspective the structure represented in Fig 43, when its sides recede from the picture at 40° and 50°, when its nearest angle is at 3 feet on the left of the spectator, 10 feet within the picture, the height of the spectator in Fig. 43 being taken at 6 feet.

The subject of the next study is a prism formed of three equal sides.

In Fig. 57 the object is placed so that the end is parallel to the plane of the picture, and in this view it will be easily understood that the end elevation will form an equilateral triangle.

Having, then, drawn the horizontal line at the required height above the picture-line, and having fixed the centre of the picture and the points of distance, draw the equilateral triangle A B C′ at the given distance on the right (or left, as the case may be) of the spectator.

From A and B draw lines to the centre of the picture, for it will be clear that, as the equilateral triangle is the section of the prism taken at right angles to its edges, when the triangular end is parallel to the plane of the picture, the edges of the prism will be at right angles to it, and will therefore converge to the centre of the picture.

Now from A set off on the picture-line A D, representing the true length of the prism, and from D draw a line to the point of distance, cutting A C in D′.

From D′ draw a horizontal line, D′ E, and it will be clear that this line, D′ E, is the perspective rendering of the length A B when at a distance within the picture equal to A D (see Fig. 11, Vol. I., p. 333); and it will also be obvious that as the distant end of the prism is in this case supposed to be parallel to the near one, it will, although diminished by distance, be an equilateral triangle, the base of which will be the line D′ E; and therefore, in the present case, it would be sufficient to construct this equilateral triangle, and draw a line uniting the apex of the first triangle to that of the second one.

But this process would not, for the purpose of instruction, be a satisfactory one, as it would only be applicable when the prism is absolutely an equilateral one. The following method is therefore given because it can be used whether the section be an equilateral, isosceles, or scalene triangle.

From C′, the apex of the original triangle, drop the perpendicular C′ F.

From F draw a line to the centre of the picture, cutting D′ E in G, and at G erect a perpendicular.

Now from C′ draw a line to the centre of the picture, cutting the perpendicular G in H. Then it will be clear that G H is the perspective height of the perpendicular F C′ when at the given distance within the picture (as shown in Fig. 8, Vol. I., page 333).

The point H is then the apex of the distant triangle, therefore draw D′ H and E H, which will complete the projection of the prism, and it will be seen that C′ F G H is a vertical section through the upper edge of the prism, dividing the whole object into two prisms, the ends of which are the right-angled triangles A F C′, D′ G H and B F C′, E G H.

CHEMISTRY APPLIED TO THE ARTS.—XI.

BY GEORGE GLADSTONE, F.C.S.

SULPHURIC ACID.

SULPHURIC ACID, or as it is commonly called "oil of vitriol," is used in the arts for such a variety of purposes, that its manufacture is a large and constantly increasing one.

Some of its uses have been incidentally mentioned in previous articles of this series. It will be found mentioned in those on bleaching, dyeing, calico printing, and soda making; but besides these uses, it enters into the composition of green and blue vitriol (the sulphates of iron and copper), and alum; is used in medicine in the form of Epsom and Glauber's salts and mineral waters; and is employed in the manufacture of ether, nitric, hydrochloric and acetic acids, and in the preparation of superphosphate of lime for manure.

This acid used to be made principally from rock or native sulphur, which occurs in many volcanic districts, but principally in that of Sicily. It had all to be imported from abroad, and at times it was found difficult to obtain an adequate supply at a sufficiently reasonable price. This compelled the makers to look for other sources of supply, and now they are almost independent of Sicily, copper and iron pyrites being used instead to a very great extent.

Sulphuric acid (H_2SO_4) contains one atom of sulphur to two of hydrogen and four of oxygen; but if we burn sulphur or roast pyrites, the gas given off will be sulphurous oxide (SO_2), which does not contain sufficient oxygen. An ingredient has therefore to be found which will readily give up to the sulphur some of its oxygen. Nitrate of potash or soda is found most suitable, as either is a very cheap article, and furnishes one more atom of oxygen. Water (H_2O) completes the formula. The ingredients used in the manufacture are therefore few and simple, and hence the low price at which this most useful acid can be produced.

The process by which the ingredients are brought into combination will need, however, a detailed description. The sulphur is burnt, or the pyrites roasted, in a furnace without any admixture of fuel, because sulphur will catch fire and burn of itself at a temperature of 302° Fahrenheit; and pyrites also will decompose with evolution of heat, so as to carry on the operation continuously when once started. When sulphur is used, it is spread upon an iron plate, which has been already heated from below, whereupon it immediately takes fire and burns slowly away, the air admitted being only just what is required to maintain combustion. When pyrites, or sulphide of iron (Fe_2S_2), is to be employed, a furnace of more regular construction has to be used, as the maintenance of the heat requires more management, and there is a large bulk to deal with, only one atom of the sulphur being driven off, the other remaining in combination with the iron. The furnace having been first heated sufficiently by burning some coke in it, the charge of pyrites is inserted through a door in the upper part, and is kept constantly supplied, the roasted ore being from time to time withdrawn through a door at the bottom.

The sulphurous oxide given off in either case passes upwards through a large flue into the first chamber. In this flue are placed some saucers containing the nitrate of potash or soda, mixed with sulphur, or sometimes nitric acid alone, which in the presence of the hot fumes of sulphurous oxide is decomposed, giving off nitric oxide (NO), which passes up the flue along with the sulphurous oxide into the chamber. The chambers into which the vapours pass vary in number and size in different factories, but they are necessarily very large, as all the ingredients of the acid are brought together in the condition of gas or vapour. Thus in one establishment where 7½ tons weight of acid are produced daily, five chambers are used, having an aggregate capacity of 178,000 cubic feet. These chambers are indeed one of the principal sources of expense to the manufacturer, for sulphuric acid is of so corrosive a character, that it is difficult to find any material that is applicable which will effectually withstand its action. The only one suitable for this purpose is lead; and it is no easy matter to build a room 80 or 100 feet long of sheet lead, which shall be thoroughly air-tight. A skeleton room has first to be constructed of open woodwork, and then lined throughout with heavy sheet lead. No solder can be used in joining the sheets together, as that would be soon eaten away by the acid, but they have to be made to overlap one another, and the space between them carefully filled in with white lead paint. Notwithstanding the greatest care, these chambers are very apt to get out of order, and they are therefore so arranged that all parts of the roof, walls, and floor can be got at from the outside for repairs.

The sulphurous and nitric oxides pass, as has been already said, up the flue into the first chamber. They will enter this near the roof; the leaden pipe connecting the first with the second chamber will be near the floor, and so on alternately throughout the series, so as to facilitate the intimate mixture of the gases with each other and the atmospheric air. In some factories, instead of having separate chambers, they have one long gallery partially divided by partitions made of sheet lead, the one partition extending from the floor upwards to near the ceiling, and the next from the ceiling downwards: this arrangement answers the same purpose of mixing together the gases in their passage through the gallery.

The nitric oxide will not, however, remain unchanged in the presence of atmospheric air, but robs the latter of some of its oxygen, and changes itself into the peroxide NO_2.

The water which is required is supplied in the form of steam. To a small boiler are connected a series of pipes, which are carried round the outside of the several chambers, and terminate in leaden pipes, which pass through the floors and walls some distance into the chambers: from these jets of steam are from time to time thrown in, which also contribute to the mechanical admixture of the gases, the position of the jets being so arranged as to produce as great a stir as possible.

But the peroxide of nitrogen cannot remain unchanged in the presence of sulphurous oxide and watery vapour, and it loses again the atom of oxygen it has already stolen from the air, which now passes in turn to the sulphurous oxide, raising that to SO_3. The sulphuric anhydride thus formed has again such an affinity for water, that it will take it up whenever present, and thus becomes converted into sulphuric acid (H_2SO_4), a thick oily liquid.

This interchange of particles is constantly going on within these leaden chambers, and the resulting acid falls down like heavy drops of rain upon the floor. As sulphuric acid will continue to absorb water in addition to the definite quantity required to complete the above formula, the amount of steam injected into the chambers should bear a certain proportion to the quantity of sulphurous oxide which has been evolved from the sulphur or pyrites. This is a matter of simple calculation. Sufficient water vapour should be supplied to reduce the acid to about a 54 per cent. solution: if it were to be made much stronger, there would be a waste of sulphurous oxide, and if much weaker, there would be a waste of nitric oxide.

When a quantity of acid of about this strength has accumulated on the floor of the chambers, it is drawn off, and has then to be distilled over, in order to raise it to the proper strength of the regular commercial acid, which should be 93 per cent. For this purpose it first passes into the concentrating pans, which are also made of sheet lead: there is generally a series of them communicating one with another, and each one slightly lower than the preceding, so that during the concentration the acid passes through the whole series. The pans have a movable covering made of sheet lead, and they rest upon plates of iron. Near the lowest pan is a furnace, the flue from which passes under the whole series, so that the flame from the furnace beats upon the iron plates on which the concentrating pans rest. Sometimes the arrangement is altered, by which a great saving in the wear and tear of the lead pans is effected. It consists in bedding them upon solid brickwork, and carrying the flue from the furnace over instead of under, so that the surface of the acid itself forms the lower side of the flue, and the nitric and sulphurous fumes are carried away through the flue with the hot air. Here any nitric and sulphurous oxide which has escaped decomposition is driven off, together with about 11 per cent. of water. As soon as the acid has thus attained a 65 per cent. strength, the operation must be stopped, as the lead would suffer if carried farther, and some of the acid would be lost, sulphate of lead being formed.

In the subsequent process, vessels of glass or platinum must be used. The danger attendant on the use of the former almost compels the manufacturer to go to the expense of platinum retorts. One of these large enough to contain 20 cwt. of acid will cost about £2,500, all the joints of the platinum being soldered with gold, the only metal available which will withstand the action of hot concentrated sulphuric acid.

The 65 per cent. acid is drawn from the lead pan into the platinum retort by a glass syphon, and here it is gently boiled. The excess of water separates, and is drawn off by a tube, leaving the acid of the full strength required, 93 per cent.

The acid has now only to be transferred from the retort to the glass carboys, in which it is kept for sale; but as it is very hot, and would infallibly crack the glass if not first cooled, it is drawn off by a long syphon made of platinum, which is encased in a hollow tube through which a stream of cold water is made to pass constantly, so that on its passage from the retort it is sufficiently chilled to admit of its being poured with safety into the carboys. It cannot be left in the platinum retort till cool, because that would involve the extinguishing and re-lighting of the fire, and a very great waste of time, so that a greatly increased number of these expensive retorts would be required in a large factory. The object of the manufacturer is, of course, to get the largest possible amount of work out of them, by keeping them incessantly going.

Sulphuric acid is used for such a variety of purposes, that it has become a very important article of commerce, and in this country more than 100,000 tons per annum are now made, the greater part of which is consumed at home, though it is shipped to almost all parts of the world. Every 100 lb. of sulphur (or its equivalent in pyrites), with 3 lb. of nitrate of sodium, will yield about 310 lb. weight of acid; the gain in weight being due to the oxygen and hydrogen, which are abstracted from the air and water within the chambers, 150 lb. of oxygen and 56 lb. of hydrogen being necessary to complete the combination. So large an amount of air is required for the supply of this oxygen that were it not for a continuous inflow through the pipe which also supplies the sulphurous oxide, the reduction of the oxygen from the gaseous state, and the condensation also of the watery vapour, would cause the leaden chambers to collapse—an accident not unlikely to happen upon the old system, now superseded, of burning the sulphur within a closed chamber. In the commercial acid there is a slight excess of water, rather more than counterbalancing the loss of sulphur during the process, which averages about 6 per cent.

There is, however, another process of making this acid, which produces a purer article than the commercial acid, and is distinguished as the Nordhausen, or fuming oil. Sulphate of iron, or green vitriol, when heated to redness, gives off its acid without further decomposition; and advantage is taken of this circumstance by the makers. The crystals of green vitriol contain a large quantity of water in combination, all but one equivalent of which is readily driven off by calcination in an oven. The calcined article is then put into earthenware retorts, which are built into a furnace, the neck only protruding, and immediately that cloudy fumes begin to issue, a receiver containing a little pure water is attached closely to the neck of the retort. The fumes of sulphuric acid are absorbed by the water, and the process goes on until all the acid has been given off: the receiver is then removed, the retort re-charged with the calcined vitriol, and as soon as the thick fumes reappear, the receiver is again attached. At each repetition of the process, the water in the receiver absorbs more and more of the acid, until it has attained its maximum strength. It is then transferred to stone-ware jars, the stoppers of which are cemented down, in order to prevent its escaping into the air. It is a thick oily liquid of 1·9 specific gravity; and contains some excess of SO_3 uncombined with water, which, being very volatile, causes it to fume, forming with the moisture of the air a perceptible cloud. The furnaces are generally so arranged, that one source of heat will serve for the calcining ovens, and sometimes as many as sixty retorts; but the process cannot conveniently be carried on upon the great scale adopted in making the commercial acid, and the cost of the manufacture is very much greater. The strength and purity of the fuming oil render it indispensable, however, for special purposes.

TECHNICAL DRAWING.—XXXVI.

PUNCHING AND SHEARING MACHINE.

We now give, in Fig. 352, a side elevation of one of the powerful machines which are employed for cutting or punching holes in plates of iron for making boilers, girders, etc. One side of the machine, A, has shears, and the other, B, a punch, so that two sets of men may work at it if necessary. Motion is given to the upper shaft, C, by a strap to the large pulley, D. Two heavy fly-wheels, E and E′, are keyed upon this shaft, and also a pinion, F, of singularly strong construction. In the lessons (see Vol. I., pages 349, 359) which treat of the teeth of wheels, it has been shown that in the case of small pinions the lower parts of the teeth are comparatively weak, and so if they were subjected to the heavy strain that the wheels of this machine have to endure, breakage would result, unless special arrangements be made to prevent it. Flanges, G and G′, are cast on both sides of the teeth, and give to them just the kind of support they require. The fly-wheels run at considerable speed, and their impetus overcomes the sudden resistance given to the punch B, or shears A, when a plate of iron is inserted. Motion from the first shaft is transmitted through a second, H, to the large centre wheel, and at each end of the shaft which carries it there is a crank or eccentric, which gives motion to the sliding-blocks that carry the punch and shears. The punch may be put in or out of gear without stopping the fly-wheels; and the balance weight, J, is intended to hold it up whenever out of work, that plates of iron may readily be inserted for punching, placed in their proper position, and then the punch started.

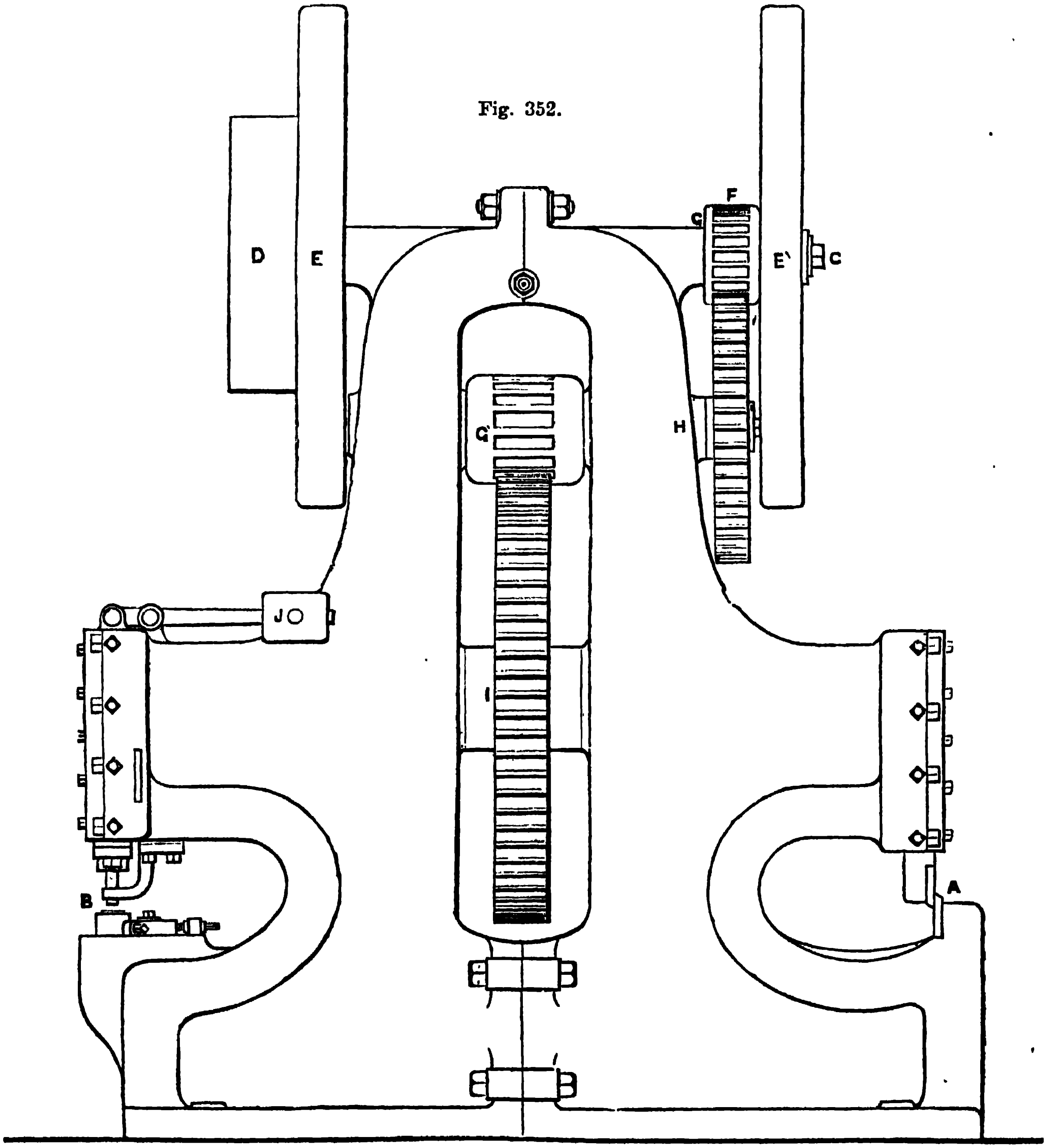


Fig. 352.

This class of tool is almost the heaviest and strongest that is made, for it has to endure a pressure of many tons suddenly applied, while the necessity of having a wide opening at the place where pressure is exerted prevents the metal offering a direct resistance to it. The illustration we have given above shows a machine of good design and strength, and excellent in the arrangement of its various parts.

DRILLING MACHINE.

Fig. 353.—This ranks with the lathe as one of the most useful tools in a workshop. The objects required in designing such a machine are to provide a vertical spindle that shall revolve at

any desired rate, and be moved up or down quickly by hand or slowly at different rates by self-acting mechanism. The lower end of this spindle must carry a drill that can be changed at pleasure.

Below this spindle there must be an adjustable table, one that will slide into any position, or rise and fall while carrying the work to be drilled, and also move aside out of the way to admit large objects under the machine.

The drill (Figs. 354 and 355) is a revolving cutter, and its object is to form circular holes in iron or other material. It is held in a chuck, as shown in the enlarged scale (Figs. 356 and 357). A small set-screw holds the steel drill in the chuck by the flattened part, so as to prevent its turning round.

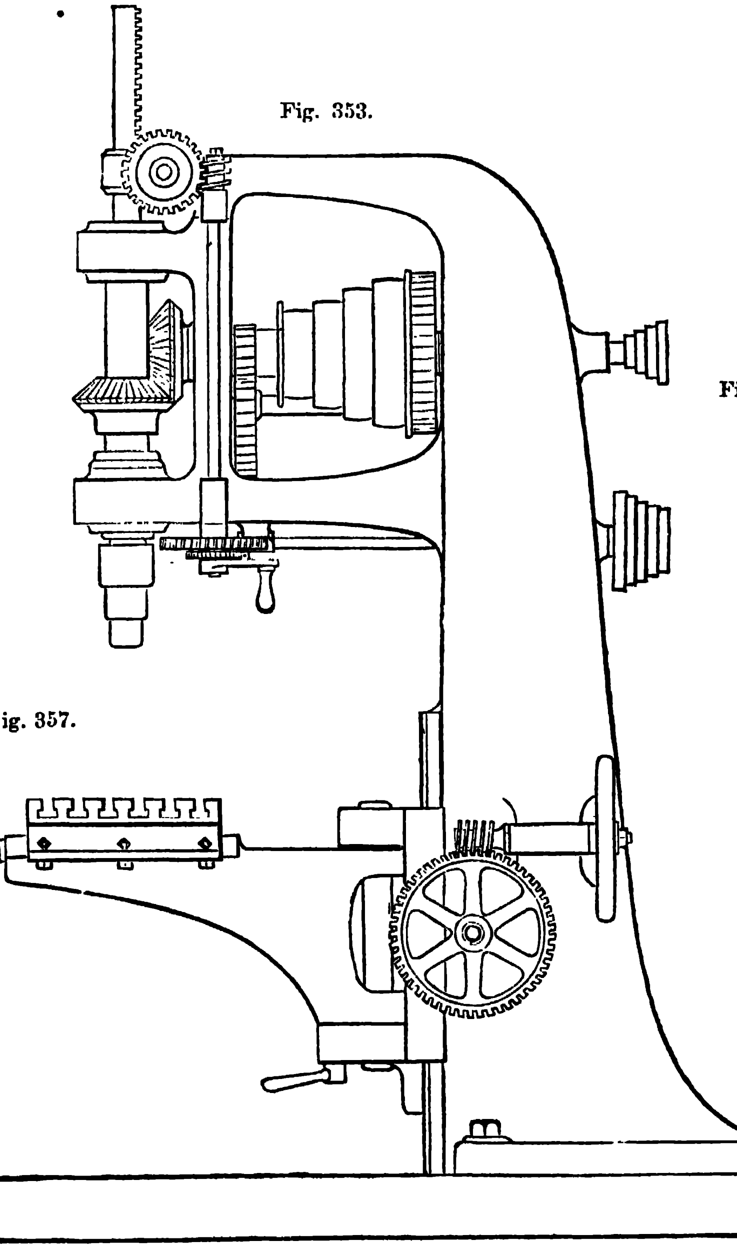


Fig. 353.

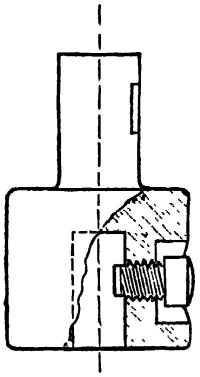


Fig. 356.

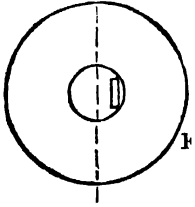


Fig. 357.

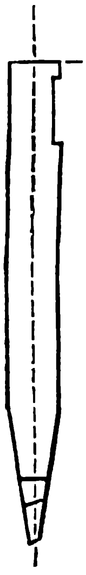


Fig. 355.

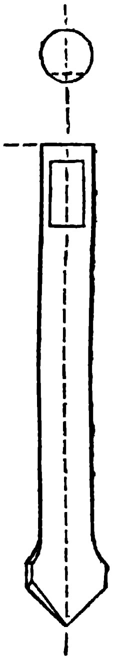


Fig. 354.

These several requirements are well attained in the drilling-machine illustrated. Motion is given to the coned pulley, and by placing the strap on the different cones four varieties of speed may be given to it. A pair of bevel-wheels communicate this motion to a hollow vertical spindle, through which passes the drill-spindle, carrying chucks and drills at its lower end. On its upper end there is a hollow shaft of the same outside diameter as the drill-spindle, which has a rack upon it, and may be raised or lowered by means of a pinion inside the framing and the worm-wheel, and worm outside. For quick speed the cone-pulley is bolted to the spur-wheel beside it, and which alone is keyed to the shaft; but for slower speeds the bolt is withdrawn, and the second lower shaft driven by the cone-pulley from the pinion at the left-hand side. A similar pinion on the second shaft communicates a reduced speed to the large spur-wheel on the primary shaft, and so transmits motion to the drill-spindle. This arrangement is precisely similar to the back-gearing of a lathe. There are two cone-pulleys at the back of the machine, which give any required motion to the worm-wheel and rack that advance the drill-spindle, while a handle conveniently placed enables an attendant to move the drill-spindle up or down by hand, or put the self-acting mechanism into gear.

Below the drill-spindle there is a level table which can slide backwards or forwards, and be raised or lowered, by a similar arrangement to that which raises or lowers the drill-spindle, or may be swung round upon a vertical shaft, and fixed in any position by means of the locking-nut below. The grooves in the table are intended to receive bolt-heads and fasten anything down upon it, and the bed-plate below is provided with similar grooves for bolting down work of large dimensions.

NOTABLE INVENTIONS AND INVENTORS.

XVI.—PRINCE RUPERT.

BY JOHN TIMBS.

"NOVEMBER 23rd, 1682, died of a fever and pleurisy, at his home in the Spring Garden, Rupert, Prince Palatine of the Rhine, etc., in the sixty-third year of his age" ("Historian's Guide," 1688). In these few lines was announced the death of Prince Robert Rupert, of Bavaria, whose checkered fortunes are prominent in the records of the Civil War, and who, though wanting in most of the qualities which constitute a great man, had a quick perception, and was active and energetic. His taste for military pursuits led him to take an active part in the stormy times in which he lived; but he was impetuous and indiscreet, unpopular throughout the country, and had the misfortune, says Lord Clarendon, "to be no better beloved by the king's party than he was by the Parliament." But he could readily change employments and pursuits, and to his possessing this serviceable quality may, perhaps, be attributed Rupert's atoning for his ill success in political life by becoming *a working inventor*. After his reconciliation with Charles II., Rupert took up his residence with the Elector of Mentz; and here, says Mr. Eliot Warburton, in the first leisure of his manhood, his mind reverted, with a sense of luxury, to the philosophical labours in which even his youth had taken pleasure. He now found new sources of interest in the forge, the laboratory, and the painter's studio.

It was during this lull in the active life of Rupert that he is said to have discovered or improved upon the art of engraving in mezzotinto. While immured in the Castle of Lintz, he had exercised his genius upon some etchings that still bear the above date. He was long said to have *discovered* the art of engraving in mezzotinto, reported to have been suggested to him by observing a soldier one morning rubbing off the barrel of his musket the rust which it had contracted from being exposed to the night dew. The prince perceived, on examination, that the dew had left on the surface of the steel a number of very minute holes, so as to form the resemblance of a dark engraving, part of which had been here and there already rubbed away by the soldier. Rupert immediately conceived the idea that it would be practicable to find a way of covering a plate of copper with little holes which, being inked and laid upon paper, would undoubtedly produce a black impression; while, by scraping away in different degrees such parts of the surface as might be required, the paper would be left white where there were no holes. Pursuing this thought, Rupert, after various experiments, invented a kind of steel roller, covered with points or salient teeth, which, being pressed against the copper plate, indented it in the manner he wished; and then the roughness thus occasioned had only to be scraped down where necessary in order to produce any gradation of shade that might be desired. This anecdote obtained currency from its being related by Lord Orford, in his well-known work upon the arts, as well as from the avidity with which origins of the arts are commonly set down as the results of accident. In short, it is said that Prince Rupert tried and succeeded, and thus became the inventor of mezzotinto engraving. If mezzotinto really had its origin in such circumstances as these, which is far from being improbable, they must have occurred to another rather than to Prince Rupert, since he certainly was not the inventor of the art, as we shall presently show.

The merit of the invention has been claimed by some authors for Sir Christopher Wren, on the ground of a communication which he made to the Royal Society, in 1662; the journals of which society for October of that year record that "Doctor Wren presented some cuts, done by himself in a new way, whereby he could almost as soon do a subject upon a plate of brass or copper as another could draw it with a crayon upon paper." Now, the engraved works in mezzotinto of Prince Rupert are not numerous, and, we believe, do not exceed twelve in number: his principal work (the "Decollation of John the Baptist," after a design by Spagnoletti) bears date 1658, which is four years earlier than Sir Christopher Wren's communication to the Royal Society. In 1662, the date of Wren's communication, the Royal Society was founded; and in the same year the celebrated John Evelyn published his "Sculpture," in which the first announcement of the new art, in England at least, appears; and he distinctly claims the honour of the invention for Prince Rupert in a chapter "on the new method of engraving, of mezzotinto, invented and communicated by His Highness Prince Rupert, Count Palatine of Rhine," etc. Evelyn embellishes the chapter with a specimen from the prince's own hand, and concludes it with alluding to an account of the process, which he is preparing to be preserved in the archives of the Royal Society. Now, as we have already seen, Prince Rupert's best performance actually bears date four years earlier, so that there is no pretence for giving the invention to Sir Christopher Wren on the ground of anything which he has produced, or any communication which he may have made in 1662. Nor are the claims of Prince Rupert more valid, since he imposed upon John Evelyn, who in turn, however, unconsciously imposed upon the world, by claiming for Prince Rupert the honour of an invention to which the prince well knew all the while that he had no title.

The real inventor of this art was Louis von Siegen, a lieutenant-colonel in the service of the Landgrave of Hesse Cassel, from whom Prince Rupert learnt the secret when in Holland, and brought it with him to England when he came over a second time in the suite of Charles II. Some curious and very rare prints, purchased on the Continent, and now deposited in the British Museum, place the claims of Von Siegen beyond doubt. In this collection is a portrait dated 1643, which is *fifteen years anterior* to the earliest of Prince Rupert's dates: there is another portrait of the same date; and another by Von Siegen bears the most conclusive evidence of its having been produced in the very infancy of the art; besides which is the fact that Von Siegen frequently attached "primus inventor" to his plates. There are also mezzotinto works by Furstenburg, dated 1656.

It should, however, be added that the works both of Fürstenburg and Prince Rupert are engraved entirely by the newly-discovered process of mezzotinto, and evince a more matured judgment of its powers than those of its inventor, Von Siegen. It is not improbable, notwithstanding what we have said, that Prince Rupert, by himself, or with the assistance of Wallerant Vaillaint, an artist whom he retained in his suite, may have improved the mechanical mode of laying the mezzotinto ground; but this observation does not apply to the principle of the art. We have abridged these details from a statement which first appeared in the "Penny Cyclopædia," and is considered to set this controverted matter completely at rest, and give the honour of the invention to its real author, the rarity of whose productions hitherto favours unwarrantable pretenders to the merit.

After the Restoration, Rupert was received with honour by the king; and Mr. Warburton tells us that the Prince established a seclusion for himself in the high tower in Windsor Castle," the king having appointed him Governor of the castle, and his residence being the Keep, or Round Tower, which the prince soon furnished after his own peculiar taste. In one set of apartments, forges, laboratory instruments, retorts, and crucibles, with all sorts of metals, fluids, and crude ores, lay strewed around in the luxurious confusion of a bachelor's domain; in other rooms, armour and arms of all sorts, from that which had blunted the Damascus blade of the Holy War to those which had lately clashed at Marston Moor and Naseby. In another room was a library stored with strange books, a list of which may be seen in the Harleian Miscellany.

The prince was an operative inventor: he toiled at his own forge, and was a scientific workman, and forged "the thunderbolts of war his hands so well could throw." We find recorded in the "Transactions of the Royal Society" Rupert's mode of fabricating a gunpowder of tenfold the ordinary strength at that time used; and curious it is to note that at the moment we write "Our Gunpowder" is being discussed in our daily newspapers. Next Rupert invented a mode of blowing up rocks in mines or under water, "an instrument to cast platforms into perspective," an hydraulic engine, a mode of making hail-shot, and an improvement in the naval quadrant. His mechanical labours include an improved lock for fire-arms, and guns for discharging several bullets very rapidly. He also discovered a method of boring guns, which was afterwards experimented in Romney Marsh by a speculator; but some secret of annealing the metal was not understood, except by Rupert, and the matter died with him. More widely known is his chemical composition called "prince's metal," of which candlesticks and small kitchen pestles and mortars are made: this is an alloy of copper and zinc; it contains more copper than brass does, and is prepared by adding this metal to the alloy. It approaches nearest to the colour of gold. The finest sort is called "pinchbeck," from its improver, and was used in making watch-cases, etc.; it is also named *tombac* (Spanish), and *petit-or* (French). These curiosities are now thrown into the shade by Abyssinian gold and electro-gilding. To the list of Rupert's inventions must be added a mode of rendering blacklead fusible, and rechanging it into its original state. His mode of tempering Kirby fish-hooks is amongst his lesser improvements. His favourite science appears to have been metallurgic chemistry.

In glass-making Prince Rupert fitted up experimental works which adjoined Chelsea College—another enterprise of the day. The Rupert Works proved a nuisance, for we find by the Council Minutes of the Royal Society that the College and lands might have been well disposed of (before 1682), but for the annoyance of Prince Rupert's glass-house, which adjoined it; and Sir Jonas More wrote to the prince, at the request of the Council, urging him to "consider the Society, on account of the mischief his glass-house was doing to the college." This was about the time that plate-glass was first made at Lambeth, in works supported by the Duke of Buckingham. "Prince Rupert's drops" take their English name from having been first made known in England by Prince Rupert, and not from his having invented them, as commonly supposed. Their origin has been much disputed. Now, a drop of fused glass falling into water might easily have given rise to the invention of these drops; at any rate, this might have been the case in rubbing off what is technically called the *navel*—that piece of glass which remains adhering to the pipe when any article has been blown, and which the workman must rub off. In a German dissertation on glass drops and their properties, published in 1695, the author states that he was informed by glass-blowers worthy of credit that these drops had been made more than seventy years before at the Mecklenburg glass-houses—that is to say, about the year 1625. They were exhibited at Kiel as early as the year 1637, and much astonished persons with their effects. They are stated to have been first made at Amsterdam, and called by the French *larmes Bataviques* (Dutch tears). Anthony le Grand states that they came from Prussia; but as the drops were the result of a common operation in glass-houses, their property may have been commonly known among glass-blowers, but not so early observed by philosophers. They were first brought into England in 1660, by Prince Rupert, and in the "Royal Society's Proceedings" occurs this entry:—"Aug. 14th. Sir Robert Moray brought in glass drops, an account of which was ordered to be registered," the experiments being made by command of His Majesty; and the first volume of the Royal Society's register book contains a very long account of them and their manufacture. Butler, in "Hudibras," says—

"Honour is like that glassy bubble
That finds philosophers such trouble;
Whose least part crack'd, the whole does fly,
And wits are crack'd to find out why."

The drop was called "a kind of miracle of Nature," and through all the universities of Europe it raised the curiosity and confounded the reason of the greatest part of the philosophers. It is thus described in the "Philosophical Transactions:"—"The bubble is in form somewhat pear-shaped; it is formed by dropping highly-refined green glass, when melted, into cold water. Its end is so hard that it can scarcely be broken on an anvil; but if the smallest particle of its taper end is broken off, the whole flies at once into atoms and disappears. The theory of this phenomenon is that its particles, when in fusion, are in a state of repulsion; but on being dropped into the water, its superficies is annealed, and the particles return into the power of each other's attraction, the inner particles, still in a state of repulsion, being confined within their outward covering." It exhibits in the most perfect manner the effects of expansion and contraction; and each possesses this singular property—that if a small portion of the tail is broken off, the whole bursts into powder with an explosion, and a considerable shock is communicated to the hand that grasps it. We remember Rupert's drops, or "hand-crackers," common at fairs, as well as "candle-bombs" (a little water in glass, hermetically sealed), which are of about the same date as the drops.

APPLIED MECHANICS.—XV.

BY ROBERT STAWELL BALL, M.A.,
Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.

FLOUR MILLS (*continued*).

The adjustment of the pressure of the upper stone upon the lower is of the utmost importance in the process of making flour. The major limit to this pressure is, of course, the entire weight of the upper stone. The adjustment consists in relieving the lower stone of part of this pressure, by transmitting it along the spindle.

To enable this adjustment to be made, the arrangement shown in Fig. 1 is used. Q R is a lever of which the fulcrum is at Q; the power is applied at the point R, by means of the screw R P; this screw passes through a hole in the fixed plate B C, and is raised or lowered by a nut; E D is the lower bearing of the mill spindle, A. The spindle, instead of resting upon the bottom of the bearing, is supported upon a piece, H L. This piece passes through a hole in the bottom of the bearing at E, and is attached to the lever Q R by a pin at H. Thus, when the end R of the lever is raised, the shaft A is also raised. It is easy to see how delicately the adjustment of the pressure can be made with this apparatus. We shall suppose that the arm Q H is one-third of the arm Q R, and that the screw R P contains six threads to the inch. We shall compute the effect upon the distance between the millstones produced by turning the nut P through one-tenth part of a revolution by means of a key or spanner. If the nut were turned round once, the point R would be raised one-sixth of an inch; when the nut is turned through one-tenth of a revolution, R is only raised by $\frac{1}{60}$th part of an inch; the point H only receives a motion which is one-third of the motion of R, and therefore H is only raised $\frac{1}{180}$th of an inch. This is therefore the distance by which the space between the millstones is increased. If the spanner by which P was turned was 8″ long, the extremity of the spanner would describe a circle 25″ long in one revolution. A movement of the end of the spanner through a space of half an inch would raise the point R through $\frac{1}{300}$th part of an inch, and the point H through $\frac{1}{900}$th of an inch. It is thus evident that this mode of supporting the vertical spindle enables the distance between the millstones to be adjusted with the nicest delicacy. This adjustment requires some skill on the part of the miller, which his experience alone can dictate.

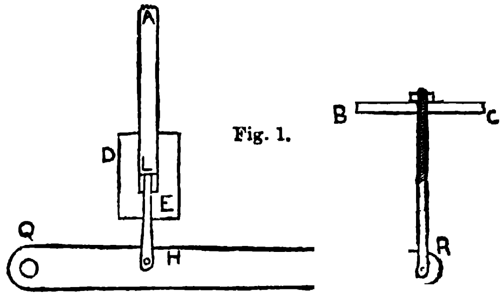


Fig. 1.

Adjustments are also provided for the upper bearing of the vertical spindle. This bearing is fixed in the hole of the lower millstone. The object of the adjustment is to provide that the spindle shall be strictly vertical. X Y Z (Fig. 2) represents the hole in the lower millstone, O is the spindle, and P, Q, R are the three bearings. These are wedge-shaped, so that by movement perpendicular to the plane of the paper, the spindle O can be adjusted vertically above its lowest point.

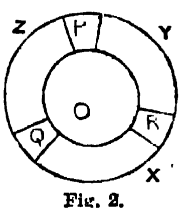


Fig. 2.

MACHINES FOR RAISING WATER.

Machines for raising water are very varied in form, according to the different circumstances for which they are required. Sometimes a small quantity of water has to be raised a considerable height: in this case ordinary force-pumps or lifting-pumps are employed. Sometimes, as in drainage and similar works, a vast quantity has to be raised from a small depth; for such purposes the chain-pump and the centrifugal pump are found to be suitable. Again, in other cases, such as raising water from mines, a large body of water has to be raised from a great depth, and pumping-engines of vast power are employed.

We may roughly divide the machines used for these different purposes into three different classes:—

1. Machines which depend upon atmospheric pressure.
2. Machines which depend upon the inertia of water.
3. Machines which simply lift the water.

To the first of these classes belong the well-known forms of the lifting-pump and force-pump. The second class includes the different kinds of centrifugal pumps and the hydraulic ram. The third class contains the Archimedian screw, the chain-pump, and very many other machines.

We shall give a description of some of the machines in each of these classes.

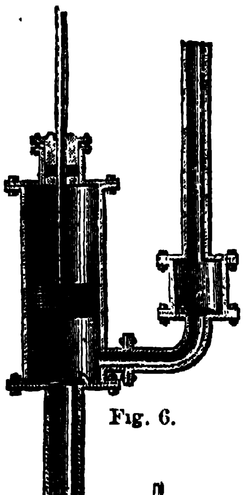


Fig. 6.

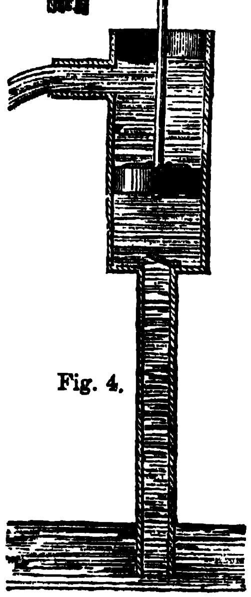


Fig. 4.

The common lifting pump is shown in Fig. 3. It consists of a hollow cylinder of brass or iron, cast with a flange at each end, and turned internally so as to be perfectly true. By means of the flanges the bottom, consisting of a circular plate, is bolted to the cylinder. This plate has a hole in its centre, and the pipe is attached to the bottom. Packing, consisting of a ring of leather or some similar material, should be placed in the joints before the bolts are tightened, in order to ensure that the joints shall be water-tight. At the bottom is a valve which opens inwards; when water rushes up the pipe it forces open the valve, and enters the cylinder; when the piston is depressed the valve closes, and will not allow the water to return.

The piston is a circular disk of metal, containing a groove in the circumference, in which the packing is inserted. The packing often consists merely of greased tow, which is sufficiently elastic to make the piston move water-tight in the cylinder. In the centre of the piston are a pair of valves, shown open in the figure. These valves allow of the passage of water from below upwards, but do not allow water to pass from above downwards.

The top of the cylinder is closed by a plate which is bolted to the flanges. The piston passes through the top of the cylinder by means of what is called a *stuffing-box.* It is easy to see that special arrangements must be made for preventing leakage where the piston-rod passes out from the cylinder. If the piston merely passed through a hole in the top of the cylinder, leakage could not be prevented. Even if the piston-rod at first fitted the hole so perfectly that it passed water-tight through it, and at the same time could move freely, this could not last; wear would soon make the piston-rod smaller and the hole larger, and leakage would result. To obviate this difficulty the very ingenious contrivance known as the stuffing-box is used. The piston passes quite freely through the hole in the cover, and then enters the stuffing-box, the object of which is to keep the packing in close contact with the rod. The stuffing-box consists of a hollow cylinder, shown in section. The cylinder is about double the diameter of the piston-rod, and in the space between the cylinder and the piston-rod the packing is placed. The packing may be made of tow and oil. The packing is forced against the piston-rod by a piece which fits freely into the cylinder. This piece is forced downwards by tightening nuts. Thus, when the piston wears a little free, leakage can easily be prevented by forcing down the piece, which will press the packing against the piston. The great power of the screw enables the packing to be pressed as closely into contact with the piston as can be desired. A pipe furnished with a stop-cock, and shown in the figure, is attached to the upper part of the cylinder.

We shall next explain the principle upon which the pump is enabled to raise water. The pipe descends into the well or other reservoir from which water is to be lifted. The piston is placed at the bottom of the cylinder and raised. The air which is in the pipe raises the valve and flows into the cylinder. When the piston reaches the top of the cylinder it is depressed, the valve at the bottom closes, and the valves in the piston open, as shown in the figure, and the air passes from below up to the part of the cylinder which is above the piston. When the piston reaches the bottom of the cylinder the process re-commences. Thus the air is gradually withdrawn from the pipe, and water rushes in to supply its place. The distance from the top of the pump to the surface of the reservoir should not exceed about 28 feet. The water will then gradually fill the tube, and on the ascent of the piston will pass into the cylinder. When next the piston descends this water will pass above the piston by the valve. At the next elevation of the piston the water above will be driven out along the delivery-pipe. The water thus raised may be taken either directly from the pipe, as in the common pump, or, as in what is called the lifting-pump, this pipe may be carried up to the elevation the water is desired to attain. A different form of pump upon the same principles is shown in Fig. 4.

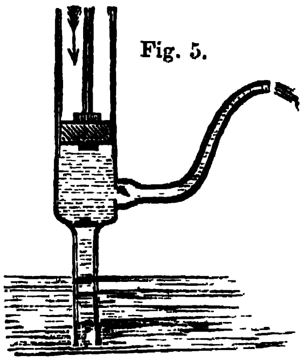


Fig. 5.

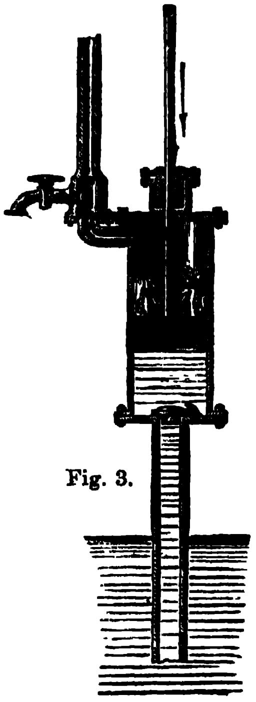


Fig. 3.

The force-pump, shown in Fig. 5, does not differ very much from the lifting-pump. In the former machine the piston is solid, and the valve regulating the escape of the water from the cylinder is placed in the side of the cylinder. The piston is shown in the figure in the act of descending. The cylinder has been filled with water raised through the valve. On the descent of the piston the valve closes, while another valve opens, and the water is forced outwards along the pipe. In a pump of this kind the stuffing-box is unnecessary, as the water does not pass above the piston. In raising water from a great depth, such as the bottom of a coal-mine, the force-pump must be within 28 feet of the water, while the discharging tube is carried up the shaft to the surface above the mine. As the engine which works the pump is at the surface, very long pump-rods are sometimes required. A different form of force-pump is shown in Fig. 6.

MINING AND QUARRYING.—VI.

BY GEORGE GLADSTONE, F.C.S.

COAL.

COKE—ADVANTAGES OF COKING—DIFFERENT QUALITIES OF COKE—VARIOUS PROCESSES FOR COKING—WASTE GASES—PATENT FUEL.

For many purposes it has been found desirable to convert coal into coke prior to using it. When an intense and long-continued heat is wanted, and where the absence of smoke is specially desired, coke may be used to advantage. It is therefore largely employed in factories in towns, and even in private buildings where there are close stoves; but still more on the railways, and in the smelting of iron. The reasons which encourage its use in the latter process will be more particularly pointed out when we come to treat of that operation; on the railways it is adopted partly to avoid creating smoke, but also because in a locomotive engine economy of furnace-room is an important consideration.

At first sight it would appear that in making coke the coal is being burnt, but though it is raised to an intense heat, that is not, strictly speaking, the case, for the result in such event would be that only the ash would be left. We have already seen in our third paper that a good coal will leave about 3 per cent. of ash, whereas the yield of coke is from 75 to 80 per cent. of the coal employed. It is the volatile and oily portions only which are consumed, leaving the carbon in a very pure condition In fact, what is classed as best coke contains (after being thoroughly dried) about 97 per cent. of carbon, 3 per cent. of ash, and a trace of sulphur. The per-centage of carbon is the criterion of the heating power, but in practice the result which these figures would indicate cannot be attained, as coke will absorb a great deal of moisture, and seldom contains less than 5 per cent. of water, for which allowance must therefore be made. The facility with which coke imbibes moisture affords dishonest traders a ready means of increasing their profits, and care should be taken by purchasers not to have to pay for more than a fair percentage of water.

Coke, though very different in appearance, is very similar in chemical composition to anthracite; and like the latter it does not burn satisfactorily without the aid of a powerful draught of air. It is hardly necessary to describe its external appearance, though some importance is attached to the bright metallic lustre; and to be well made and of good quality it should be uniform in character throughout.

The old method of making coke was to roast it in heaps in the open air; and the plan is still kept up in some places, though it is wasteful and does not produce so good an article. It has the advantage of requiring no outlay for plant. These heaps are sometimes circular in shape, while at others they are made in the form of long ridges, sometimes 200 feet in length.

In making the circular heaps the larger lumps of coal are placed upon the ground, and the smaller pieces form the upper and outer portion, until a depth of about two and a half to three feet, and a diameter of twelve to sixteen feet, is attained; a chimney made of loose bricks forms the centre, draught-holes being left between each brick. A few air-channels are left between the large lumps of coal which form the base of the mound, extending from the centre to the circumference, the rest of the heap being covered closely with coke-dust or other waste stuff to exclude the air. Some burning coal or wood is then put down the chimney, which soon communicates its fire to the mass around it. At first a dense cloud of smoke, caused by the bituminous portion of the coal, issues from the chimney; but by the time the fire has pervaded the whole mass, that disappears, and its place is occupied by a blue lambent flame, indicative of the evolution of the gases; as soon as the latter fades away the top of the chimney and all the sources of air are closed up, and the coke, being made, is left for two or three days to cool down, when it is ready to be drawn. For this purpose care has to be taken that the air is thoroughly excluded, or it will continue to burn; and it is usual to put a thicker coating of dust on the windward side. Formerly no chimney was used in these heaps, but a number of holes were left in the mineral, and fire applied to each, no protecting covering of dust being put on until the fire had spread to all parts of the pile: this was, however, very wasteful, as the surface coals were partially consumed, instead of being coked, before the lower portion was sufficiently heated.

The round heaps are not generally found so advantageous as the ridges, because the mass in the former is so great that the outer portions are often insufficiently coked, in which case the coke will be found to retain a portion of its hydrogen and oxygen.

The ridges or rows are long and narrow, sometimes extending 200 feet in length, and have an air-passage running through their whole length, the row being commenced with large lumps of coal inclined towards one another, so as to leave a triangular space between them. The smaller pieces are heaped up till it is about four feet high, and the whole is closely covered with coal-dust. About the distance of every seven or eight feet there is an upright stake extending from the air-passage; this is drawn out, and fire put down the aperture, which rapidly communicates its heat to the surrounding coal, so that the whole ridge is soon aglow, each one of these natural chimneys being in communication with the longitudinal air-channel. As soon as the coking is complete the supply of air is stopped, and the mass left to cool as before.

In some places large open kilns are used, in which 150 tons of coal can easily be operated upon at once. They are generally about fourteen feet wide, ninety long, and seven and a half high. In the walls of the kilns are openings to admit the air, and the large coal is so arranged that the air-passages shall communicate with these openings. The outside of these being fitted with dampers, the draught can be regulated very conveniently. The surface of the coal inside the kiln is covered with coal-dust as in the open heaps. The mass of coal in these kilns is, however, so large, that there is a risk of burning away the coals in the neighbourhood of the air-passages before the rest of it becomes properly carbonised. It is therefore doubtful whether in the end anything is gained by their adoption.

This leads us to the consideration of the most approved method of coking—viz., in ovens. This plan is now very largely practised. The simplest form of coke-oven is a circular building of fire-brick, with a doorway in the front, covered in with a rather flat vaulted roof, in the top of which is an opening. The oven is filled with coal up to about the springing of the roof; the doorway is then filled in with loose bricks so as to allow the entry of a little air; and as the coking proceeds the door is more effectually closed by plastering it up with clay and sand, beginning at the lowest row of bricks and working upwards, the topmost row being left untouched for some hours longer. When all flame has disappeared, the hole in the roof is also closed with a stone slab, and every crevice stopped up with loam. After remaining shut out from the air for about twelve hours, the charge is ready to be drawn. The door is then broken open, and the coke is drawn out by means of rakes into iron barrows or trucks and carted away. Some water is often sprinkled upon it immediately on its being drawn from the oven, to cool it more rapidly. Nothing is said here about setting fire to the coal; in fact, that is not needed to be done, for the coking operations go on continuously day and night, and the ovens are never allowed to get cool, so that the heat radiated from the walls and roof is sufficient without further assistance to set the charge on fire.

Various improvements upon this rudimentary form of coke-oven have been made, and some that have been proposed really convert them into elaborate structures. Some of the principal modifications, and the reason for them, must however be noticed.

As a matter of economy, it is of importance not to allow any more of the heat to escape than can possibly be avoided. The walls are therefore made very thick, and the roof covered over with sand or some other bad conductor of heat. A coke-oven never stands alone, but a number are built together, so that one shall keep the other warm: they are generally arranged in a double row, back to back. Many of the best ovens have a double roof, and the waste gases from the coal pass through the space between the two roofs on their way to the chimney. One tall chimney serves to carry off the gases from a large number of ovens; and by a little careful management very little smoke need be produced during the operation, as it is only in the earlier stage of the coking process that smoke is produced at all. The waste gases are often made to contribute still more to the maintenance of the heat in the ovens, by the flues being carried through the walls and under the floor of the ovens, so that the gases have to make a considerable circuit before passing away. This arrangement possesses the special advantage of expediting the action in the lower portion of the charge, which in the simple ovens is the last part to get coked, as the heating there commences at the top and gradually works downwards.

In many of the improved ovens the supply of air is not limited to what enters by the upper portion of the door, but is admitted by small air-passages passing through the walls in various parts, but always above the surface of the charge; the supply from these can be regulated with much nicety, and the air is thus distributed equally over all parts of the charge, instead of being all directed upon one point.

The raking out of the coke when made is not only a hot and laborious process, but the time occupied by it allows of the ingress of a great deal of fresh air, which tends materially to cool the oven itself. Both these objections are obviated by the use of what is called the *drag*. It consists of an iron bar which lies along the floor of the oven from the door to the back, with a long piece of flat iron fixed at right angles. This is put in its place at the back of the oven, before the coal is introduced, and remains there throughout the process: when complete a chain is attached to the fore end of the iron bar, and with the help of a windlass the whole charge is drawn out in one mass. Where the drag is used the lower part of the oven must be rectangular, and the width of the door increased.

Figs. 12, 13, 14, showing the *plan*, *elevation*, and *section* of coke-ovens, will serve to illustrate the foregoing descriptions. They represent a portion of a double row of eighteen ovens, communicating with a chimney stalk 115 feet high. These ovens have iron doors, which are hung with counter-weights, and raised or lowered by a crane. Within is a second door made of fire-bricks. The exterior of the ovens is bound with iron. The floor rests upon a bed of concrete, and the supply of air can be regulated by the damper plates in the channel connecting the oven with the flue. Every alternate oven is charged in succession, so that while the one is having the coke drawn and being re-charged, those on either side are at their full heat. Each oven treats three and a half tons of coal at a time.

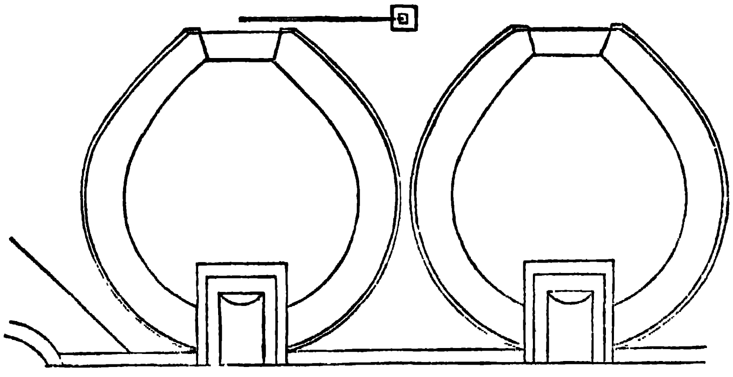


Fig. 12.—PLAN OF OVENS.

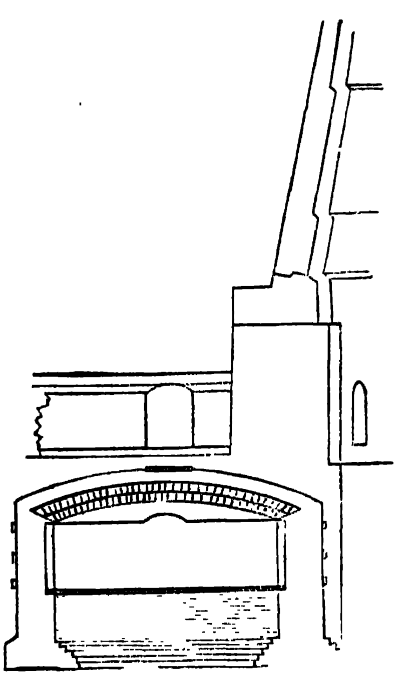


Fig. 14.—SECTION OF OVENS.

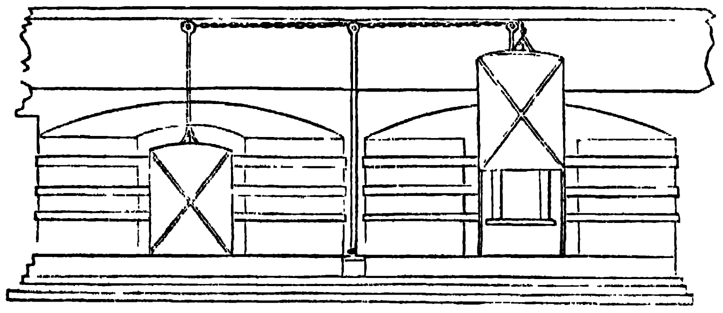


Fig. 13.—ELEVATION OF OVENS.

The amount of heat which is generally wasted is very considerable, but it may be easily turned to profitable account. Thus at the large iron-works of Seraing, in Belgium, the boilers for the steam-engines are erected over the coke-ovens, so that twenty-four ovens supply all the heat required to work two engines, by which a saving of nine to ten tons of coal per day is effected.

The coking process does not altogether drive off the sulphur contained in coal, and to reduce the quantity of this obnoxious ingredient the coal is sometimes washed first, and some add a little common salt in order to convert the sulphur into sulphate of sodium.

It is well known that coke is not the only product of coal which is yielded by the agency of heat; but the others are not regarded by the coke-burner, because a different temperature from that which suits him best are needed for their production. The common illuminating gas is the most familiar of these articles, which is produced by distillation at a high temperature; and though a quantity of coke is left in the retorts of the gas-works, it is of a different character from that described here, and is of very little value as an article of fuel. Gas-making will be treated in a separate series. The tar and other oily hydro-carbons are evolved, on the other hand, at a temperature somewhat below a dull red heat: some of the products of these are described in "Chemistry applied to the Arts," papers II. and IX. All these substances, both gaseous and liquid, are sacrificed to the carbon in the coking process, while in the other the quantity of carbon desired is only so much as will enter into chemical combination with the hydrogen.

Patent Fuel.—Small coal and coke-dust have lately been economised by converting them into patent fuel. Several patents have been taken out for this purpose, and there are some very large establishments in England and Wales for the working of them. The general principle involved in them is to work up the slack and dust with just sufficient coal-pitch or tar to make it cohere, and then compress it into solid blocks. For this purpose the materials have to be somewhat warmed, so that the pitch becomes softened, and the mixture reduced to a pasty mass. In order to make a hard fuel which shall stand a hot climate without fear of spontaneous ignition, the heat is raised to 400° or even 600° Fahrenheit, by which means the more volatile ingredients are all driven off. Such fuels are much used on board steam-vessels; and for navigation purposes the small coal used in their manufacture is generally that derived from the best steam coals: being made into blocks considerably larger than ordinary bricks, and all of uniform size, they are very easily handled, are very economical in stowage, and cause less dust, which are all considerations of some importance on shipboard. The analysis of a good patent fuel will give about 86 to 90 per cent. of carbon, and the specific gravity will vary, from 1·13 to 1·18. The loss in actual density of the fuel as compared with large coal is balanced by the closeness with which the blocks can be stowed on shipboard.

A fuel may even be prepared from some kinds of small coal without the use of pitch or any other ingredient of that kind. By selecting that derived from a good caking coal, and heating it up just to the caking point, it will cohere sufficiently to form a firm block after it has passed under heavy pressure.

The unavoidable production of coal-dust is so great, that the accumulation of it in large workings leads to much inconvenience. In the face, too, of the rapid consumption of large coal, these appliances for turning to account the heaps of coal-dust which were formerly considered as dead loss, cannot but be regarded as of the highest importance.

PRINCIPLES OF DESIGN.—XVII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS.

It is not my intention in this chapter to consider in detail the various kinds of carpet which are common in our market, nor even to review the history of their manufacture, interesting as it would be to do so; for we must confine ourselves more particularly to an examination of the art-qualities which they present, and to the particular form of pattern which may be applied to them with advantage.

Although we cannot here enter into a consideration of the manufacture of carpets, I cannot too strongly recommend all who intend preparing designs for them to consider minutely the powers of the carpet loom; for the nature of the effect produced will depend to a large extent upon the knowledge which the designer possesses of the capabilities of the manufacture for which he designs patterns. In the case of any manufacture it is highly desirable, if not absolutely essential, that the designer of the patterns to be wrought should be acquainted with the process by which his design is to be converted into the particular material for which the pattern has been prepared; for this knowledge, even when not absolutely essential, gives an amount of freedom and power which nothing else can supply.

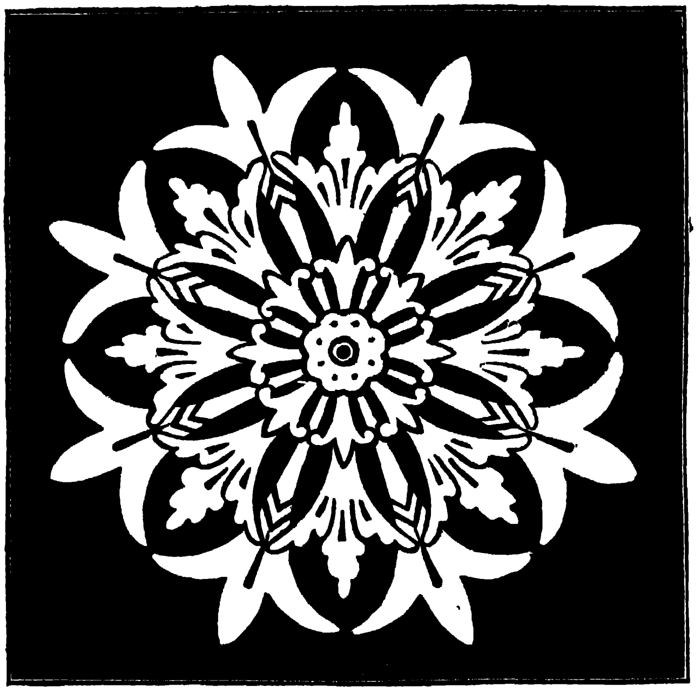


Fig. 54.

The carpets most extensively in use are "Brussels;" but there are many other kinds both of better and inferior qualities. "Kidderminster carpet" (a carpet not now made by even one Kidderminster manufacturer) is a common fabric suited to the bedrooms of middle-class houses; but the art-capabilities of this material are very small, as it can only have two colours in any line running through its length. This carpet consists of two thicknesses, which are imperfectly united, and is not durable. "Brussels carpeting," now made chiefly in Great Britain, is a good carpet for general purposes. Its surface consists of loops, and it may have five, or, if made of extra quality, six colours in any line running throughout its length. If with five colours in the same line the carpet will, in a sense, consist of five thicknesses of worsted; yet these are united into one fabric. In some cases a "Brussels carpet" is woven of very close texture where the loops are all cut through; thus we have formed a "velvet pile" or Wilton carpet"—a fabric which is very rich looking, and durable.

Those called real "Axminster" carpets are, perhaps, the best made. They are formed by the knotting together of threads by hand, consequently any number of colours may be used in their formation; but such are necessarily most costly. A "patent Axminster" carpet is made by a double process of hand-weaving, by which fine results are achieved, and any number of colours used. In the first weaving a rough "cloth" is formed, which is cut into strips called "chenille threads," and these are woven into the carpet. This process is most ingenious, and the carpets produced by it are very good; but they are costly.

Messrs. Crossley and Sons, of Halifax, some few years since patented a most ingenious process of manufacturing what are known as "tapestry" carpets—a process resembling in its nature that of the patent Axminster manufacture, but differing in this particular, that the "warp" threads, answering to the chenille threads of the patent Axminster, are coloured by printing, and thus the first process of weaving is dispensed with. These carpets are, like Brussels, made with a looped surface, and also with a pile. They cannot be said to compare in any way with the patent Axminster carpets, which are of a pretentious and costly character, nor even with a good "Brussels;" but they are low in price, and meet a want, as is proved by their enormous sale.

Besides these varieties of carpet there are a number of kinds of foreign production, most of which are hand-made, and are very beautiful. By far the greater number of these have a "pile," although this is sometimes rough and uneven, yet rarely, if ever, inartistic; but a few are without pile; still these are not without that indescribable something which renders them estimable in the eye of an artist.

Having hastily noticed the chief kinds of carpet in use in this country, and we might say in almost all countries, we come to the question—what form of pattern, or what character of ornament, should form the "enrichment" of such a fabric?

When speaking in a previous article (see page 119) of wall decorations, we noticed that a wall-paper pattern, or, indeed, a wall pattern of any kind, might desirably have an upward direction and a bilateral symmetry. This can never be the case, however, with a carpet pattern, which must be equally extended all over the surface, or have a simple radiating symmetry, as Fig. 54; and this rule will apply whether the pattern be simple or complicated. It is not wrong, as we have said before, to have a radiating pattern on a wall, but it is wrong to have such a pattern on a floor.

The reason of this is obvious. If such an object as we have indicated is placed on a wall, from whatever point the occupants of the room may view it, it is yet right way upwards to them; but if such an object were placed on a floor it would be wrong way upwards, or sideways, or oblique to most of those who viewed it; and to employ a pattern of this character in such a position is highly absurd, when a pattern can as readily be formed of such a character as will avoid this unpleasantness. What would we think were we asked to view a picture, or even to visit an apartment containing such, were this work of art presented to our view in an inverted manner? We should feel astonished at the absurdity; yet this would be no worse than expecting us to view a carpet while the pattern is to us in an inverted position.

And the principle which we have just set forth is one taught by a consideration of plants. If we wander over the moor, where we tread on Nature's carpet, we find that all the little plants which nestle in the short mossy grass are "radiating ornaments"—that is, they are pretty objects which consist of parts spreading regularly from a centre.

I cannot too strongly advise the young ornamentist to study the principles on which Nature works. Knowledge of the laws on which plants grow is very desirable; yet it is not our place to *imitate* even the most beautiful of plant-forms—this being the work of the pictorial artists. Yet it is ours to study Nature's laws, and to observe all her beauty, even to her most subtle effects, and then we may safely pillage from her all that we can *consistently* adapt to our own purposes. But in order that we produce ornament, we must infuse mind or soul into whatever we borrow from her.

With the view of more fully impressing the manner in which Nature teaches us principles which we may apply in art, and of aiding the student in his inquiries, we will give one or two illustrations. Thus Fig. 55 is a drawing of a spray of the guelder rose (*Viburnum opulus*) when seen from the side, or, as I might express it, when viewed as a wall decoration; and Fig. 56 is the same spray as seen from above, or, to use the same manner of expression, when seen as a floor pattern. Further, Fig. 57 represents a young plant of a species of speedwell (*Veronica*) as a wall ornament, and Fig. 58 the same plant when seen as a floor ornament; and Figs. 59, 60 represent a portion of the goosegrass (*Galium Aparine*) as seen in the same two views.

From these illustrations we see that plants furnish us with types of two essentially different ornaments which are adapted to the decoration of the two positions of wall and floor, and may be introduced with truthful expression and effect into wall-paper or carpet.

Even when the leaves appear somewhat dispersed upon the stem, a principle of order can yet be distinctly traced in the manner of their arrangement, as is diagramatically expressed in Fig. 59; and here, also, the top view gives us a regular radiating ornament.

The same law prevails in the flower that we have traced as existing in the arrangement of leaves upon the stem: thus Fig. 61, which represents the London pride (*Saxifraga umbrosa*), affords an example of a regular radiating flower, which we find so placed, in different examples, as to appear as a floor or wall ornament; and Figs. 62, 63, the former being the flower of the speedwell (*Veronica*), and the latter that of the common pansy (*Viola tricolor*), furnish us with illustrations of bilateral flowers intended only as wall ornaments. In order to secure our seeing the pansy only laterally, it is furnished with a bent stalk; hence it never rests horizontally upon the summit of its stem, but always hangs so that it is perfectly seen only from the side.

There are cases, however, in which bilateral flowers are placed horizontally; but it is very interesting to notice that when this occurs the disposition or arrangement of the flowers is such as to restore the radiating symmetry. Thus, if we take the candytuft (*Iberis*) or the common hemlock (*Conium*), we find that while each flower is bilateral in character, the flowers are yet arranged around a centre in such a manner that the smaller portion of each flower points to the centre of the flower-head, while the larger parts point outwards from the centre of the group. These, then, are the teachings of plants, to which we are called upon to hearken.

The above illustrations are not only useful examples of the adaptation of plant-forms to ornamentation, but form excellent guides to the art-student for the conventional treatment of leaves and sprays, buds and blossoms. They will also serve to indicate the kind of plant-forms that should be chosen for decorative purposes. Students of this branch of art would find it a useful practice to make a collection of any flowers and plants or parts of plants that appear to offer features similar to those of which we have been writing, and test their capabilities for decorative purposes, by endeavouring to arrange them for ornamentation of wall and floor, as we have treated the plant-forms named in this paper.

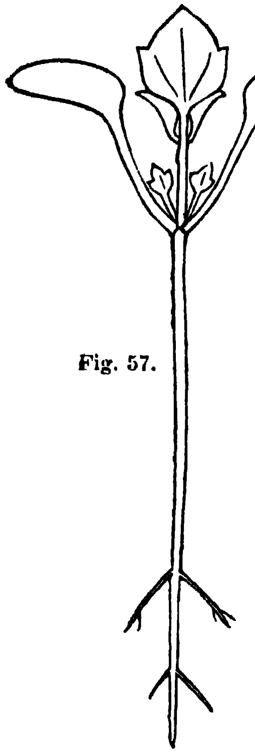


Fig. 57.

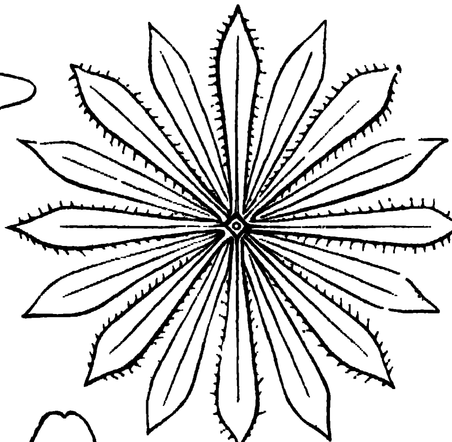


Fig. 60.

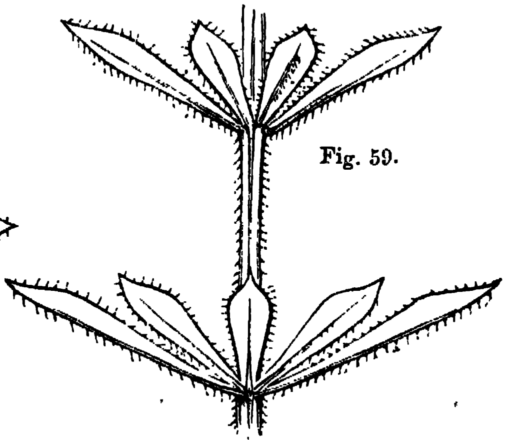


Fig. 59.

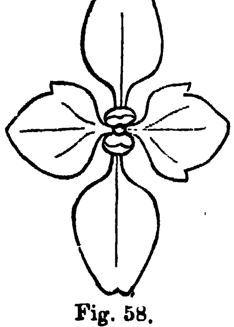


Fig. 58.

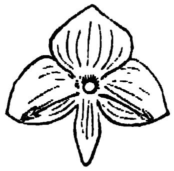


Fig. 62.

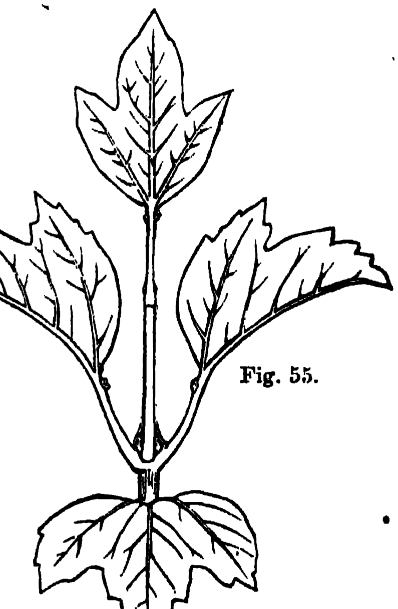


Fig. 55.

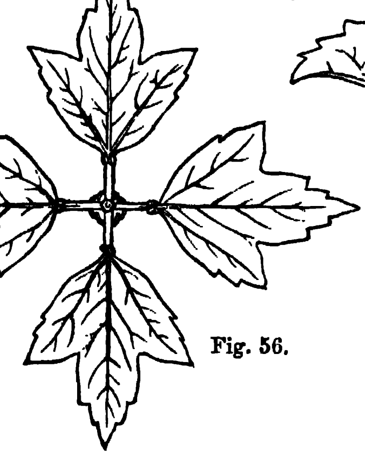


Fig. 56.

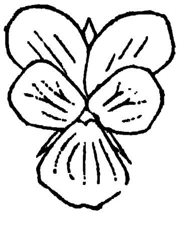


Fig. 63.

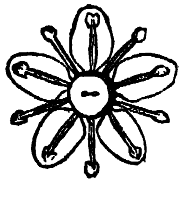


Fig. 61.

THE ELECTRIC TELEGRAPH.—XI.

By J. M. Wigner, B.A.

BONELLI'S PRINTING TELEGRAPH — ALPHABETICAL INSTRUMENTS—BREGUET'S—WHEATSTONE'S UNIVERSAL.

In our last lesson we described several forms of chemical telegraph; there is, however, one more to which we must refer before we leave this class of instruments. This is known as Bonelli's Printing Telegraph, and by means of it the message is printed in ordinary Roman characters, and that too at an almost incredible speed. It is said by those who have used the instrument that, when the message is printed in fugitive ink, a speed of more than a thousand words a minute may be attained, and in permanent characters from 200 to 300 words may be sent in the same time. There is, however, one very great drawback to the use of this instrument, and that is the fact that it requires five wires, and thus it can only be made to pay on lines where a great many messages are continually passing.

The instrument consists virtually of five pointers placed side by side, each of which acts in the same way as the one pointer or pen in Bain's instrument. The message is first set up in metal type, block letters and capitals being employed. Ordinary printing type will not answer, however, since it is left-handed, and, besides, is so soft that the metal would soon wear away. Brass letters are therefore used, and when set up they are placed on a metal tray connected with the earth-plate, and made to pass under the pointers.

Of these there are five, which are placed side by side like the teeth of a comb, and are connected with the five line-wires. At the receiving station are five somewhat similar pointers, connected with the corresponding wires, and the chemically prepared slip is made to pass along under these, so that, if constant currents were passing, five parallel lines almost touching one another would be traced on the slip. The current, however, only passes when the raised part of a letter comes against a contact-spring or pointer, and thus the marks traced correspond to the raised parts of the type, and we have an almost exact copy of the type printed at the receiving station.

An enlarged copy of a message as received by this instrument is given in Fig. 48, and will explain the whole action.

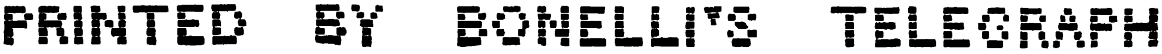

PRINTED BY BONELLI'S TELEGRAPH

Fig. 48.

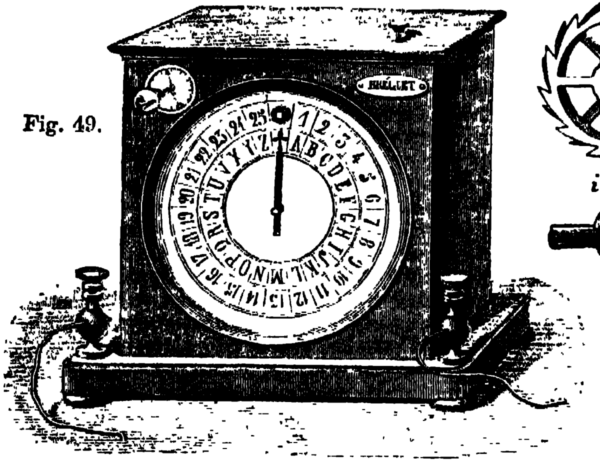


Fig. 49.

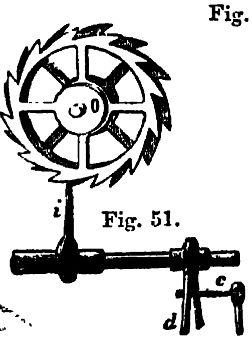


Fig. 51.

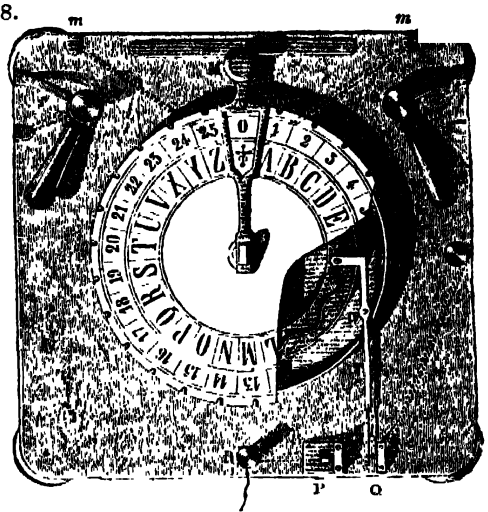


Fig. 52.

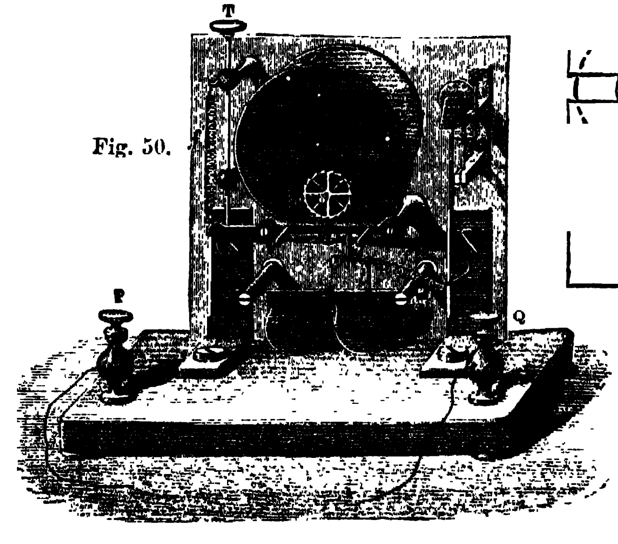
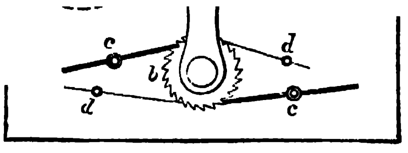


Fig. 50.

Fig. 54.



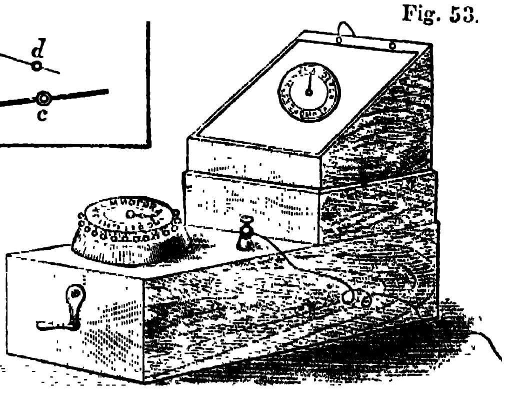


Fig. 53.

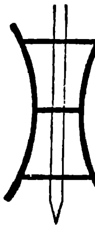


Fig. 55.

This instrument is a very ingenious and reliable one, but, for the reason referred to, it has not come into general use. The whole class of chemical telegraphs are in fact chiefly valuable as showing what may be accomplished by means of electricity; none of them, we believe, being practically employed in this country to any great extent at the present time.

We must now pass on from these instruments to our last class—namely, the alphabetical or dial instruments. In most of the telegraphs already described the message is sent in some cipher or code, and the instrument can only be used by the initiated, some considerable amount of practice being required to attain even moderate facility in its use. For many reasons, however, it is a great advantage to have an instrument so simple that any one with a little care and understanding can work it. This is especially the case where, as is frequently done in the present day, a wire is fitted between two or more different offices of any house of business, or between an office and a factory.

Very many instruments have accordingly been invented in which a pointer is made to travel round a dial on which the letters of the alphabet are engraved, and to stop at any required one; so that the message to be sent may be spelled out in this way letter by letter. These are sometimes distinguished as step-by-step motion telegraphs. We cannot even mention all the different instruments of this kind that have been introduced, but will describe one or two of those which best illustrate their construction, and from these the action of most others may, with a little thought, be understood.

Breguet's Alphabetical Telegraph will convey a good general idea of this class of instruments. In it, as in several we have already described, the receiving and transmitting portions are entirely distinct. Fig. 49 represents the former of these, and Fig. 50 a back view of the same instrument, the case, and also the magnet, which occupies a position facing the dotted circles on A, being removed for the sake of clearness.

Round the face are placed the 25 letters of the French alphabet and the sign +, which is given at the end of each word, while in an outer circle the numerals from 1 to 25 are arranged.

In an English instrument there are usually 30 divisions on the dial-plate, for the 26 letters, the comma, semicolon, full stop, and +. Inside the case is some clockwork, which is wound up by the axle seen on the face between 25 and 1. This clockwork causes the hand to travel round the face at a considerable speed, but its motion is stopped or regulated by the escapement seen at Q, an enlarged view of which is given in Fig. 51.

It consists of two ordinary scape-wheels mounted on the same axle in such a way that the teeth of one are alternate with those of the other. A small pallet, *i*, is fixed under this, and is so arranged that as it vibrates backwards and forwards, it alternately catches the teeth of each wheel; in this way, each movement of the pallet allows the wheel to revolve one twenty-sixth part of a revolution, and as the hand on the dial-plate is fixed to the axis of this wheel, it allows the hand to move forward one letter.

We have now to see the way in which this movement of the pallet is controlled by means of the electric current which arrives along the line-wire, and passes round the coils of the magnet. The keeper or armature, A (Fig. 50), is suspended so as to swing freely on pivots fixed in the supports V V′, and carries with it a small arm, *l*, having a pin, *c*, inserted at one side of it. A spiral spring, *f*, passes from the top of *l* to a wire fixed to the stand, and thus keeps the armature away from the magnet when no current is passing.

The armature therefore swings to and fro as the circuit is made and broken at the sending station, and this alternate motion is communicated through *l* and *c* to the fork *d* (Fig. 51), and thus to the pallet *i*, which at each movement allows the hand to move forward one letter. If then it be set to +, and a current be transmitted along the line-wire, the hand will move forward to A, and there remain as long as the current passes. As soon as it ceases, the spiral spring will draw away the armature from the magnet, and the hand will move to B. Thirteen currents are thus required to allow the hand to complete its revolution round the dial, and the transmitting apparatus has to be so arranged that we may easily cause the required number of currents to be sent so as to stop the hand at any given letter.

Sometimes, however, the hand will get wrong, owing to the receiving clerk interrupting the message, or from some other cause. A small rod with a milled head, T, fixed to it, is therefore provided. By pressing on this the pallet is entirely removed from the scape-wheel, which, being thus set free, rotates until the hand points to +, where another stud stops it.

The transmitting apparatus, which is far simpler in its construction, is shown in Fig. 52. It consists of a large dial-plate with the letters arranged round it just as in the receiving instrument, and a small notch is cut in the rim opposite each letter. A handle, M, is fixed to a pivot in the centre, and has an opening or slot cut in it. This is moved round in one direction following the order of the letters, till the one we wish to send is seen through the slot. A small peg in its under side catches in the notch against the letter, and ensures it stopping at the right point. If by any chance the handle is moved beyond the letter, we must not move it back, but must carry it quite round till it again comes to the required letter.

A portion of the dial is removed in the figure, and shows a wheel underneath, which turns with the handle. In this wheel a sinuous groove is cut, having thirteen elevations and as many depressions. A small roller fixed to a pin on one end of the bent lever T works in this groove, and thus for every revolution made by the hand M, this lever is moved from side to side thirteen times.

At the lower end of T is a spring faced on each side with platinum; as the lever vibrates this comes alternately into contact with the screws P and Q, the former of which is connected with the line-wire. The battery-wire is connected to *m*, and thence the current passes to the grooved wheel, and along the lever T.

We can now understand the action of the apparatus. Let us move the handle to the letter A, the lever T will at once be moved till its lower end comes in contact with P. The current will then pass from the battery, through the wheel, along T, and by way of P to the line-wire. It will then cause the magnet at the receiving station to attract its armature, and thus let the hand there move to A likewise. If now we move the handle to B, the lever will be inclined to the other side, and the current will thus be interrupted. The magnet at the other end then ceases to act, and the armature being released, lets the hand move forward another letter to B. In this way, we have only to move the handle to any letter we like, and the same letter will be indicated at the other end. The message is thus spelled out letter by letter, a short pause being made between each.

The handles seen at the upper sides of the receiving instrument serve to make the current pass to the alarum, or the receiver, at pleasure.

At the end of each message the handle is turned twice round to show that it is complete, and the receiver, if he has understood, acknowledges by a similar sign.

This instrument is an electro-magnetic one, and requires a battery; there are, however, several somewhat similar ones, which are purely magnetic, and in which, therefore, all the trouble of a battery is avoided. The one of these most generally used was invented by Wheatstone, and is now employed on nearly all the private lines in London.

In this the receiver is usually made to stand on the upper part of the transmitting apparatus, as seen in Fig. 53. The latter consists of an oblong rectangular box, on the top of which near the front is a raised dial-plate with the letters of the alphabet and the signs , ; . and + engraved round it. In the centre is a hand which is moved by a handle in front, and points successively to these various signs.

Outside each letter is a small stud or button which can be pressed down by the finger; these are so arranged that when one has been depressed, it remains so until another is pressed down, but the act of doing this raises the former, so that only one stud can be down at the same time. In the front is seen a small handle which is continuously rotated by one hand, the other being employed in pressing down the required studs. When that opposite any letter is touched, the pointer is free to move round to that letter, and there it remains until another stud is pressed down, so that in sending the message we have merely to press down in succession the studs corresponding to the letters, and thus spell it out.

Inside the instrument is a second hand fixed to the same axis as the pointer and turning with it. This is so placed that when any stud is depressed it catches against it and stops its further progress. The movement of this pointer is thus entirely mechanical, but an arrangement is also made by which at the same time a short circuit is made, so that no more currents pass along the line till the hand is again free.

One great advantage of this instrument is that the armature is kept constantly rotating by the handle. In this way its movement is much more regular, and the danger of the needle "skipping" is greatly reduced. The internal mechanism is simple; several thin horse-shoe magnets are screwed together to form a compound one of considerable power, and two bobbins wound with fine wire are placed side by side on each pole. The cores of these four are arranged in a circle, and the keeper rotates in front of them. The alternate bobbins are wound in reverse directions.

When the armature, which turns on a pivot in the centre of the four bobbins, is in front of the first and third, a momentary current is produced, which travels along the line-wire; as the armature passes to the alternate pair, a current in the reverse direction is generated, and thus by the continuous motion of the armature alternate currents are sent.

The armature and pointer are both set in motion by the handle seen in front of the instrument, and are so adjusted that for each current sent the pointer advances one letter. As soon as the pointer is arrested by any stud, the currents are, as we have seen, intercepted.

We must now turn our attention to the receiving apparatus, in which there is a small dial and hand similar to the large one. The currents pass round two slender bobbins, placed side by side, the ends of which are represented by the dotted circles in Fig. 54. Between these there is a pair of magnetised needles reversed and mounted as seen in Fig. 55, and the alternate currents cause this compound to oscillate, the opposite poles being alternately attracted and repelled. To the upper end of their axis is fixed the arm *a* (Fig. 54), which carries the ratchet-wheel, *b*. As this arm oscillates, the slender screws, *c c*, alternately catch in the teeth of *b*, and thus at each movement advance it half a tooth, or one letter on the dial, for the pointer is fixed to the axis of this wheel. The hair-springs, *d d*, prevent the wheel moving unevenly.

A small handle is always provided under the upper dial by means of which the needle may, when required, be brought to +. If at any time the receiving clerk fails to understand a word, he at once interrupts by working his own instrument. This throws both needles out; both operators then cease working, taking care to leave the large pointers at +; they then bring their receiving pointers to the same sign, and are ready to resume. If the needles do not all agree at starting, it is clearly impossible to make the message understood.

An alarum is always used with this instrument, and by moving to the left the lever seen behind the receiver, this is brought into circuit, and the receiving instrument shut out.

We have ourselves used an instrument of this kind for a considerable time, and found it very simple, and with ordinary care not liable to get out of order.

TECHNICAL DRAWING.—XXXVII.

DRAWING FOR STONEMASONS.

A CONCISE HISTORY OF MASONRY.

ALTHOUGH the purpose of these lessons is to teach drawing of precisely the kind necessary for stonemasons, still it is hoped that a brief sketch of the history of masonry will not be unacceptable.

The art of building in stone is one of the greatest antiquity, dating possibly from the first human family. We find that when Cain was driven by his sin to become a wanderer from his native place, and when a son had been vouchsafed to him, he "builded a city," and called it, after the name of his son, Enoch (Hebrew, *dedication*). We have, of course, no data to give us the slightest idea of the extent of the buildings which constituted this primitive city, but, from the word used in the original, it is most probable that permanent structures of the form of caves were erected.

There can be no doubt that from the moment when our first parents were driven from Eden to till the ground and to labour, they must have felt the necessity for some place where their children might be nurtured and protected from the rays of the sun.

The umbrageous trees and the skins of animals might at first have proved sufficient; but a better shelter would at once have been suggested by holes in rocks or natural caves. These, however, could not be found everywhere. What is more natural than that wooden huts should be erected, and that these, being perishable, should, when circumstances allowed, be superseded by stone buildings. And thus the trunks of trees, and beams laid across them, probably gave the original ideas for the columns and architraves of the subsequent erections in a more permanent material.

Amongst the earliest nations of the world heaps of stones were regarded as a memorial of some event, or as emblems of the permanency of the agreement entered into. Thus we find Jacob took a stone and set it up for a pillar, and said to the people, "Gather stones," and they took stones and made a heap, and both parties called it by a name which, in the language of each, signifies "the heap of witness." Several such instances occur in sacred history.

Amongst rude and barbarous people there seems in all ages to have existed this desire to erect huge masses of stones, either to commemorate some triumph, or for the exercise of their religious rites; and the early history of almost every nation contains records of some such structures.

Of the early history of stone-work, Mr. Ashpitel says: "The necessity for defence against predatory tribes seems to have given the next impulse to building in stone; and to this we probably owe those extraordinary walls called Cyclopean or Pelasgic. These consist of huge polygonal blocks of stone carefully cut, so as to fit exactly to each other without mortar, forming walls which must have been impregnable at that time."

An idea of their size may be gathered from the fact that in the Etruscan walls at Rusellæ, Mr. Dennis measured a stone 12 feet 8 inches long by 2 feet 10 inches high. Most of the stones forming these walls would weigh from six to eight tons. It seems very difficult, considering the deficiency of machinery at the period, to imagine how they were hoisted. Pausanias,[*] describing those of Argolis, says: "The walls, the only remains of the city left, are the work of the Cyclops, and are made of rough blocks of such a size that a yoke of mules would be unable to move the smallest."

The masonry practised in Assyria possesses this peculiarity—that, excepting at the angles, it formed only a facing to the immensely thick walls, which were filled up in a manner to be subsequently described; and it is especially interesting to us from its great antiquity.

Mr. Layard, to whom the world owes so much for his discoveries in Assyria, tells us that 600 years before the Christian era, Nineveh ceased to be a city, and Assyria an empire. Cyaxares, at the head of a vast army of Babylonians and Persians, captured Nineveh after a short siege, destroyed its walls and palaces, and left it what it has remained to this day—a heap of ruins. The Assyrians, after the destruction of their capital, became subjects of the King of Babylon, and appear no more in history as an independent people.

The main cause of the utter disappearance of Nineveh is to be found in the circumstance that the buildings were not erected of stone, but merely faced with it; and not always this, for their palaces, public buildings, and private dwellings were erected of bricks made of clay, mixed with chopped straw—in most cases dried in the sun; but, evidently, stone was not a general building material, for in erecting the Tower of Babel we find the people saying, "Come, let us make bricks, and burn them thoroughly" (thus implying that *thorough* burning was not usual); "and they had brick for stone, and slime (*bitumen*) had they for mortar."

Marble, alabaster, and kiln-burnt bricks, sometimes painted and sometimes glazed, were used by the Assyrians in their principal buildings, but only in the way of ornament. The whole of the upper portions of the buildings were of wood, and hence, when the buildings were once deserted, the upper portions decayed and fell in. The sun-burnt bricks, which formed as it were the core of the walls, became earth again. Their support thus being withdrawn from the slabs, the ruins assumed the appearance of mere natural heaps or mounds rising in the plain, upon which grass grew and corn might be sown. And such have been the ruins of Nineveh for more than 2,000 years.

The Assyrian palaces and public buildings were erected in terraces thirty or forty feet above the level of the surrounding country. These platforms appear to have been supported by solid masonry of limestone. The line of elevation was broken by flights of steps or inclined ways, by which the terrace was reached. "The object," says Mr. Layard, "of raising these great platforms, which must have demanded scarcely less labour and expense than the superstructure they were destined to sustain, was twofold—to give to the royal or sacred edifices additional dignity and grandeur, and to secure, in a climate remarkable for its intense heat during the summer months, as much coolness as possible. In some cases, too, especially in the lowlands of Babylonia, they may have served both as a means of defence and to protect the buildings against the effects of the inundations to which that country is subject." Several of the alabaster sculptured slabs, and of the human-headed bulls brought from Nineveh, may now be seen in the British Museum, and copies of them form parts of the admirable reproductions in the Nineveh Court of the Crystal Palace at Sydenham.

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[*] Pausanias, a Greek geographer, who lived in the second century. He wrote "Accurata Græciæ Descriptio," in which he gives a very minute account of the topography of Greece, and of its buildings and ruins as seen by himself.

The Egyptians seem not only to have used gigantic masonry, but also to have had the power of working, carving, and polishing granite to a marvellous degree. A strange fact connected with their masonry seems to be, that the whole work was executed with copper, or rather bronze tools, which seem to have answered their purpose better than even our best or hardest steel. Such seems to have been the facility with which they worked this untractable material that they were not content to cut and polish huge slabs and masses of granite, but they covered them all over with the most delicate and sharp-cut hieroglyphical inscriptions.

Mr. Owen Jones, to whom we are indebted for the admirable reproductions in the Egyptian Court at the Crystal Palace, says: "Egyptian architecture, or rather Egyptian art—for painting, sculpture, and architecture are so intimately united that they are inseparable—is the parent of every other. Undoubtedly the most ancient, its remains are still the most abundant. The Egyptians built for immortality, and obtained it. Whilst obedient to religious laws which limited the direction of their art, they combined the highest sublimity of conception with the most refined and delicate finish in execution."

Whilst they originated, they excelled at the same time all that followed after; they are inferior only to themselves. In every other nation, art exhibits its progress in the same phases, namely, a rapid ascent from its infancy to the culminating point of perfection, from which there is a slow, lingering decline; but in Egypt, the farther we go back the more perfect is the art. We are not even acquainted with its culminating point, much less with any trace of its infancy. In the most perfect temples which have been discovered there are stones built in the walls, with hieroglyphics on the inner side, of a higher character of art than can be found on existing monuments. These were evidently stones from ruins of more ancient buildings. Two kinds of walling were common in Egypt from the earliest to the latest period *—one formed of vast rectangular blocks of stone laid in parallel courses, the other of sun-dried brick. The latter was used for walls of towns and sacred precincts, and occasionally for pyramids, but never for any part of a temple.

The stone walls were of prodigious thickness and the blocks of gigantic size; but in the early Theban works we find little of that interlacing of the stones, or *bond*, which is so essential to stability. This partly accounts for the ruined state of some of those tremendous masses—gigantic walls of the most massive construction, and absolutely rent asunder. The masonry of the pyramids, however, appears to be excellent. Unlike the migratory Pelasgi, to whom reference has already been made, the Egyptians seem to have used mortar from the earliest ages. The blocks were also commonly united by wooden dovetailed cramps about a foot in length.

The columns ordinarily employed were of such colossal dimensions that they were necessarily *built up*—each cylindrical layer being composed of several stones. They were commonly constructed with blocks rough-hewn externally; the shaft was afterwards finished, and the capital chiselled to the proposed design. A whole rough-hewn colonnade is still to be seen in the isle of Philæ.

Walls appear to have been left rough till they received their sculpture, and Herodotus † intimates that a similar method was followed at the Great Pyramid: having been carried up to the full height, it was finished off from the summit to the

Mr. George Godwin, in his admirable "History in Ruins," says:—"The most ancient structure remaining is the Great Pyramid—one of those mighty works wherein, as Dénon says, men seem to measure themselves with Nature. Herodotus, who visited Egypt about 450 years before the Christian era (some say 500), or more than 2,300 years ago, spoke even then with uncertainty as to its date. It is, however, usually ascribed to Suphis (or Cheops), who reigned soon after Menes, and may be called 4,000 years old—Bunsen says 5,000."

Herodotus says: "The ascent of the pyramid was regularly graduated by what some call steps, and others altars. Having finished the first flight, they elevate the stones by the aid of machines constructed of short pieces of wood; from the second by a similar engine to the third; and so on to the summit. The summit of the pyramid was first of all finished; descending thence they regularly completed the whole"—that is, they placed plates of stone slantingly from one step to the other, and so produced a uniformly slanting mass.

The dimensions of the Great Pyramid have been differently stated, the mounds of rubbish rendering it difficult to obtain accurate measurements. Those taken by Colonel Vyse's operations in 1837, probably nearest the truth, are as follow:—Original base, 764 feet; actual base, 746 feet; original inclined height, 611 feet; actual perpendicular height, 450 feet.

The original perpendicular height, therefore, supposing the pyramid to have been carried up to a point, was about 480 feet, or 43 more than St. Peter's at Rome, and 110 more than St. Paul's Cathedral, London. The area covered was almost 13½ acres, but the approximate size of the mighty mass will be better understood if it is described as a solid pile, the base of which would occupy the whole square of Lincoln's Inn Fields, and the height of which would exceed that of St. Paul's. The stones employed in the construction vary from five to thirty feet in length, and from three to four feet in height.

According to Pliny,* 366,000 men were employed on its erection for twenty years, and Herodotus tells us that an inscription on the exterior stated the expense of providing them with radishes, onions, and garlic amounted to 1,600 talents of silver (£345,600). Ten years were employed in making the road through which the stones were to be drawn, the quantity of which Colonel Vyse estimates at 3,316,000 tons.

Thus thousands of enormous stones, all accurately squared and adjusted, were here elevated to hundreds of feet above the ground, and each was hoisted up step by step, until it reached its bed.

The Pyramids, however, although they attest the resolution of the founders, reflect but little honour on the Egyptian nation. One can scarcely contemplate these structures without the conviction that they were the work of an enslaved and driven race. Such vast piles of mere stone and mortar could never have been reared in Greece or Rome. At the Parthenon or at St. Peter's you view the result of the labours of a multitude of ingenious and thinking men, each contributing the skill derived from a life devoted to his art; but in the erection of the pyramids little else was required of the artificers than physical exertion and obedience to the taskmasters—and, indeed, nothing was done for the labourers which could elevate or educate them. All we find in relation to the workmen is a record of the amount spent on onions for them!

How different this from the present age, when all civilised nations are vying with each other in the promotion of the instruction, the mental improvement, and social well-being of the working classes!

The first material used by the Greeks in their buildings was timber. They then employed bricks, the art of making which they learnt from the Egyptians; common stone followed next; and when they had accomplished the complete glories of their style, they adopted marble. The sort called Parian was the most admired, but this was principally used in sculpture. Pausanias also tells us that in the earlier times several temples were built of *bronze*. Stones of immense size, after the manner of the Egyptians, were also used by the ancient Greeks. In later periods smaller stones were used; these were of various forms, having in some cases four, and in others five or six sides, and were joined with the utmost care and nicety.

As architecture and other arts advanced, the Greeks used cubical and oblong stones, with which they constructed their walls, says Vitruvius,[*] in two principal methods—one called *isodomon*, in which all the courses were of an equal thickness; and the other *pseudisodomon*, in which they were all unequal. The first, or true manner, was always used in their grandest buildings, as being the most beautiful; and the latter, or false method, where beauty of appearance was of less consequence.

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* Wathen's "Arts and Antiquities of Egypt."

† Herodotus, a celebrated Greek historian born at Halicarnassus in 484 B.C. and died 408 B.C.

* Caius Plinius Secundus, a great Roman writer who lived in the first century. He was suffocated by the vapours caused by the eruption of Mount Vesuvius, A.D. 79.

Another and still inferior mode of walling was also used by the Greeks for works of lesser consequence; this was called *emplecton*. The front stones only of this manner were wrought, and the interior left rough and filled in with stones of various sizes or rubbish. This style was principally used in walls of great thickness, such as those surrounding cities. In some instances the walls were built of bricks or common stone, and faced with marble.

Cement was seldom used by the Greeks in their best works, as the size and weight of the blocks and the great exactness with which they were squared were sufficient for solidity, and of course made more perfect and complete joints.

The Greek architects of the best period were judiciously careful that the ornamentation should in every case accord not only with the purpose to which the building was to be devoted, but that it should be appropriate to the situation in which it was to be placed. Thus they never built a prison in the Corinthian (or most graceful and highly decorated) style, nor a theatre in the severe and solemn Doric. The external ornaments are bold and sparingly distributed, and as they are to be exposed to light, they stand out in high relief from the surface, so as to cast bold shadows. This is called *alto-relief*, whilst the system of ornamentation used for less exposed situations was that called *bas-relief*, in which the figures or objects project only partially from a flat surface, like a raised painting. Both of these styles may be studied from the model of the Parthenon, or Temple of Minerva, at the Crystal Palace, in which the ornamental sculpture will be observed in its place, whilst a portion of it is placed of the size of the originals along the walls of the gallery. The originals, called the Elgin Marbles, may be seen in the British Museum. Amongst these will be seen several figures—such as Theseus, Hercules, and Ilissus, a river god, which formed portions of the groups in the pediment, or triangular portion surmounting the pillars of the portico. These were absolutely separate from the background. (Figures placed in this manner may be seen in the pediment of the Royal Exchange, which faces the Poultry, London.) The Elgin Marbles[†] also comprise the celebrated Frieze—a broad horizontal band of sculpture which was placed around the outer wall of the *cella*, or principal chambers of the temple, within the cloister or covered walk which surrounded the building. This remarkable work represents the solemn procession to the temple of Minerva during the Panathenæan festival, and has never been equalled for elegance of composition and the variety and gracefulness of the figures. It is executed in low relief, in order to adapt it for its precise position; for as it was placed high up on a wall, in a narrow corridor, the lower part of the figures would, had they stood out in a high relief, have hidden the upper from the vision of the spectator, who was precluded from stepping back to view them at a distance; and, further, the frieze, placed as it was within the colonnade, received its light from between the columns, and by reflection from below, and therefore figures projecting far from the background would have cast shadows in an uncertain or contradictory manner.

This exquisite frieze occupied slab after slab, a space of 524 feet in length. The remains of it in the British Museum, on slabs and fragments of marble, are to the extent of 249 feet, besides 76 feet in plaster casts. These sculptures were designed by Phidias,[‡] and were executed by him, or under his superintendence.

The masonry of the Greeks was, as has been said, executed in the most beautiful marble, the workmanship being worthy of the costly material; the joints, etc., being worked with the most exquisite refinement and truth, whilst the artistic work has not been surpassed in any subsequent period. "It seems difficult to believe," says Mr. Ashpitel, "that so enlightened a people were ignorant of the use of the arch, especially as it is clear that it was known not only to the Egyptians, but was used in Nineveh. However, no example of a Greek arch exists at this time as an architectural feature, although for necessary purposes (as covering drains) and concealed in the walls (as discharging arches) examples are to be found in Greek works. It is probable that, as they had plenty of marble in blocks of almost any size, they preferred to use it in horizontal bearings to working it into arched forms."

AGRICULTURAL CHEMISTRY.—IX.

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CHAPTER IX.—PHOSPHATIC MANURES.

THE phosphatic manures employed chiefly in these countries are bones, guano, and superphosphate of lime; but the manufacturers of artificial manures employ as raw materials various mineral and organic phosphates which the farmer does not use directly for manurial purposes.

Bones consist of organic matter (chiefly gelatine), which is combustible, and mineral substances, which are incombustible; they also include a considerable amount of water. By boiling bones by far the greater portion of their fatty constituents and a proportion of their gelatine are removed. When kept for some months after being boiled their composition is generally found to be nearly the following:—100 parts of dried boiled ox-bones contain—

Moisture	10
Organic matter	28
Tricalcic phosphate (bone phosphate of lime) .	54
Magnesic phosphate	2
Calcic carbonate	4
Alkaline chlorides and sulphates . . .	1
Insoluble matters	1
	100

When the bones are fresh or "green" they often contain nearly half their weight of water. It is always the more economical plan to buy the very driest bones, even if they are apparently very dear. Ox-bones appear to be better than sheep-bones, whilst the latter are considered superior to horse-bones, at least for manurial purposes.

The amount of nitrogen in bones is considerable, and is sometimes equivalent to nearly 5 per cent. of ammonia. On the average, I have, however, found in commercial bone-dust only from 2·5 to 3·7 per cent. of nitrogen. During the decay of bones in the soil the nitrogen is chiefly converted into ammonia — fourteen parts of nitrogen uniting with three parts of hydrogen (which is also a constituent of bones) form seventeen parts of ammonia.

As fat is a useless addition to the soil, bones should be boiled to deprive them of their grease; the value of the fat should more than compensate for the cost of boiling the bones. The liquid in which the bones are boiled contains, after the removal of the fat from it, an important amount of nitrogenous matter; this liquid should therefore be preserved, and added to the manure-heap.

The bones met with in commerce are often grossly adulterated with gypsum, coprolites, sand, and marl; and I have found so much as 50 per cent. of extraneous matter in bone-dust. "Half-inch" bones are less liable to be adulterated than quarter-inch; whilst unbroken bones cannot readily be tampered with without detection. Large bones deposited in the soil remain there for very many years before they undergo complete decomposition. When they are reduced to very small fragments, by means of the bone-mill, they are rendered far more active as a fertilising agent. Under any circumstances, however, bones are a slowly-acting manure, and are best adapted for pastures, where fertilising matters need only be slowly applied. The action of bones may be hastened by fermenting them before their application to the soil. The bones should be mixed with half their weight of earth, piled up into a heap, and kept saturated with the strongest liquid manure from the house. In about three or four weeks the bones will be found thoroughly fermented, and their hard structure softened. The late distinguished agriculturist, Mr. Philip Pusey, whilom President of the Royal

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[*] Vitruvius, a celebrated Roman architect, born about 80 years B.C. (see TECHNICAL EDUCATOR, Vol. I., p. 39).

[†] The Elgin Marbles were brought from Greece by Thomas, seventh Earl of Elgin, and purchased from him by the nation for the British Museum in 1816 for the sum of £36,000.

[‡] Phidias, a famous sculptor of Athens. He died B.C. 432.

Agricultural Society of England, employed fermented bones in green crop husbandry with remarkable success. He believed himself to be the inventor of this method of treating bones, but in this respect he was mistaken, as it was practised, though rarely, many years before his experiments were undertaken. Bones subjected to the action of high-pressure steam decompose much more readily in the soil than the finest bone-dust; but steamed bones are very rarely used as a manure.

In South America the bones of oxen and other animals are burnt upon a very large scale; and the incombustible residue is, under the name of bone-ash, largely exported to Europe, where it is chiefly employed in the manufacture of artificial manures. This substance contains from 68 to 76 per cent. of tricalcic phosphate, the average proportion being 71 per cent. The other ingredients are moisture, calcic carbonate, alkaline salts, carbon, and insoluble earthy matters. Farmers very rarely use bone-ash as a manure *per se;* but it is one of the commonest sources of phosphates used in the manufacture of superphosphate of lime and other artificial manures.

In the chapter on guanos, I referred to those which contain but a trace of nitrogen, and which are only valuable on account of their phosphates. The following table shows the average composition of some of the phosphatic guanos now in the market:—

COMPOSITION PER 100 PARTS OF PHOSPHATIC GUANO.

	Maldon Island.	Mejillores.	Pacific	Howland's Island.
Moisture	10·0	10·0	9·5	16·0
Organic matter and ammoniacal salts	9·0	7·5	14·0	8·0
Containing nitrogen, equal to ammonia	(0·05)	(trace)	(0·30)	(0·40)
Tricalcic phosphate	73·0	75·0	40·0	73·2
Calcic sulphate (gypsum)	3 0	—	—	—
Calcic carbonate (chalk)	4·0	—	30·5	—
Alkaline salts	0·5	5·5	3·3	2·5
Insoluble matters	0·5	2·0	2·7	0·3
	100·0	100·0	100·0	100·0

In the year 1840, Baron von Liebig, in his celebrated work on "Agricultural Chemistry," suggested that the fertilising action of bones might be greatly hastened by treating with sulphuric acid. This admirable suggestion was shortly afterwards carried into effect by Mr. Lawes, of Rothampstead; and it has been the means of creating a new and extensive branch of manufacture in these countries and in other parts of the world—I refer to the manufacture of superphosphate of lime, and other manures of the kind. As I have already explained, bones dissolve slowly in the soil, because their constituents are in a hard and firmly coherent state, and in coarse fragments. By Liebig's process the bone ingredients, but more especially the phosphates, are rendered soluble or pulpy, in which state they are readily dissolved by the solvents which are present in the soil, and presented in an assimilable condition to the crops.

Bones acted upon by sulphuric acid (oil of vitriol) constitute the commercial article so familiarly known to agriculturists under the names of superphosphate of lime, and dissolved or vitriolised bones. I shall now explain the nature of the changes which take place when bones are converted into superphosphate of lime.

Tricalcic phosphate (familiarly known to farmers as bone, or insoluble phosphate of lime) is composed of three chemical parts or atoms of the metal calcium,[*] united with one atom of phosphoric acid. This compound is insoluble in pure water, but it is sparingly soluble in water containing carbonic acid, ammoniacal salts, and even common salt. The water which percolates the soil contains the various matters which enable it to dissolve tricalcic phosphate, and the finer the particles of the latter are the more readily are they taken up into solution. When two parts of sulphuric acid are poured upon one part of tricalcic phosphate, the latter parts with two of its atoms of calcium to the acid; the remaining atom of calcium and the atom of phosphoric acid constitute monocalcic phosphate, commonly termed biphosphate or acid phosphate of lime. The two atoms of calcium separated from the tricalcic phosphate, and the two atoms of sulphuric acid form two atoms of calcic sulphate (gypsum, or plaster of Paris).

Tricalcic phosphate is insoluble in water, whilst monocalcic phosphate readily dissolves in that liquid; nevertheless, plants do not take up monocalcic phosphate from the soil, for if they did it would act corrosively upon their tender tissues. The instant monocalcic phosphate is placed in the soil the calcium, which (as chalk) is invariably present in the latter if fertile, unites with the monocalcic phosphate, and converts it into tricalcic phosphate. What, then, it may be asked, is the utility of converting insoluble phosphate into soluble phosphate, when the latter becomes again insoluble when placed in the soil? Simply that the bone phosphate may be got into the finest possible state of division. The most powerful mill only reduces bones to a coarse and hard powder, but the precipitated phosphate formed when soluble phosphate is deposited in the soil is as soft as jelly, and yields easily to the action of the solvents contained in the soil. Tricalcic phosphate contains—

Lime	53·86
Phosphoric acid	46·14
	100·00

According to Berzelius, its composition when derived from bones is, after ignition—

Lime	51·26
Phosphoric acid	48·74
	100·00

It requires 156 parts of tricalcic phosphate to produce 100 parts of monocalcic phosphate. Every part of biphosphate of lime as a manure is equal to 1·56 parts of bone phosphate made soluble.

100 parts of boiled bones and 35 parts of brown oil of vitriol, thoroughly mixed, and allowed to remain for a month, usually have the following composition per 100 parts:—

Water	16·0
Organic matter and combined water	20·0
Containing nitrogen, equal to ammonia	(2·0)
Biphosphate of lime	18·0
Equal to bone phosphate made soluble by acid	(28·0)
Phosphate of lime	8·0
Sulphate of lime	35·0
Alkaline salts	1·5
Insoluble matters	1·5
	100·0

This manure would be rather damp, and should be dried with peat-mould or fine clay.

1 ton of bone-ash acted upon by 18 cwt. of brown sulphuric acid will produce about 38 per cent. of soluble (not *biphosphate*) phosphates.

There are several minerals which contain large proportions of phosphoric acid. *Phosphorite* is a white, hard stone, containing upwards of 70 per cent. of the tricalcic phosphate. The white mineral termed *apatite* is a compound of three atoms of tricalcic phosphate with one of calcic chloride and one of calcic fluoride; the green mineral termed *moroxite* has a similar composition. The brown pebbles found in large quantities in various places in the east of England, and termed coprolites (from the erroneous idea that they were the fossilised excreta of extinct species of animals), consist of from 50 to 60 per cent. of earthy phosphates, mixed with calcic carbonate and fluoride, and insoluble earthy matters. Enormous quantities of coprolites have been raised in England during the last thirty years, and their use has tended greatly to economise the production of superphosphate of lime. Phosphate of aluminium is likely to be soon largely employed in the preparation of artificial manures. Mr. Spence, of Manchester, has recently patented a process whereby he proposes to convert the alumina in the phosphate into alum, and its phosphoric acid into superphosphate of lime. I have examined the native phosphate of aluminium which Mr. Spence proposes to use in his process, and I find that it contains phosphoric acid equal to nearly 70 per cent. of tricalcic phosphate.

Mineral superphosphate is prepared by pouring sulphuric acid (specific gravity 1·6 to 1·7) on phosphorite or coprolites. The phosphate of calcium in such minerals as coprolites is useless; it should, therefore, be wholly converted into soluble phosphate, so that not the slightest portion of insoluble phosphate should remain. For every per cent. of chalk in the coprolites, 1 per cent. of sulphuric acid (specific gravity 1·7) should be used; and for every 10 per cent. of earthy phosphate, 8 per cent. of acid. As deleterious fumes are given off during the mixture, the process is conducted in a close chamber, provided with a flue to convey the gases and vapours into a chimney. The coprolites are ground into a powder before being used, and the finer the powder is the more readily does it yield to the action of the acid. When the superphosphate is made it is always found in a hard mass, and it must be broken up by a pick or spade. In manure factories there is a machine called a disintegrator used for this purpose. On a small scale, coprolite or bone superphosphate may be made in a wooden tank, 12 feet long, 5 feet wide, and 2 feet deep. To protect the wood from the action of the acid, the inside of the tank should be coated with pitch.

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[*] Calcium and oxygen in union constitute quick or burnt lime (calcic oxide).

Although the price of superphosphate of lime is generally about £7 per ton, the composition of the article varies considerably, some specimens being nearly twice as valuable as others. It is necessary, therefore, that the farmer should never purchase superphosphate of lime, or any other kind of artificial manure, without receiving a guaranteed analysis, showing its composition. A good bone superphosphate should include from 22 to 26 per cent. of soluble phosphates (bone phosphate made soluble) to 14 per cent. of insoluble phosphates, and from 1·2 to 2 per cent. of ammonia. A mineral superphosphate should include from 26 to 35 per cent. of soluble phosphates; any insoluble phosphate which it may contain being considered worthless.

In purchasing a manure the farmer has to consider the cheapest sources from which he can obtain soluble phosphates, insoluble phosphates, and ammonia. I have drawn up the following table of the money value of the different ingredients of manures, founded upon the prices at which they may be obtained at present from the cheapest sources :—

MONEY VALUES OF THE CONSTITUENTS OF MANURES.

	Per ton.		
Ammonia	£80	0	0
Biphosphate of lime[*]	30	0	0
Phosphate of lime	10	0	0
Sulphate of lime	1	10	0
Alkaline salts (soda and potash compound mixed)	2	0	0
Potash salts	16	0	0
Organic matter	0	10	0

Recently manufacturers have not been able to obtain sulphate of ammonia under £16 to £18 per ton. This salt contains 25 per cent. of real ammonia; and, therefore, in it the farmers may purchase ammonia at the retail price of £80 per ton.

Biphosphate of lime is of equal value to the farmer, whether prepared from bones, bone-ash, or coprolites. It cannot, however, be produced as cheaply from guano or bones as from minerals; but that is a matter which concerns the producer and not the consumer of soluble phosphates. The manufacturer can procure phosphate of calcium at £6 per ton in coprolites; whereas it costs him £8 10s. per ton in bones (allowing for the value of their other ingredients), and £9 15s. per ton in phosphatic guanos. But why make soluble phosphates from bones or guano? Bone-soluble phosphate is precisely the same thing as coprolite-soluble phosphate; no chemist could discover the slightest difference between them, for there is none. Therefore, in even the so-called bone superphosphate, the biphosphate should be derived from a mineral source; whilst the insoluble phosphates should be in the form of bone-dust, or soft guano.

The farmers can purchase insoluble phosphates in bones or bone-ash, at about £10 per ton; but if they buy phosphatic guanos, they pay from £13 to £15 per ton for the phosphates which they contain. Although guano phosphates are soft, and probably dissolve pretty readily in the solvents in the soil, I consider the price at which they are at present sold beyond their real value; and farmers would act wisely if they bought their ammonia in the form of sulphate of ammonia, their soluble phosphates as a mineral superphosphate, containing 30 per cent. of biphosphate, and their insoluble phosphates in the form of bones or bone-ash. 1 cwt. of sulphate of ammonia, 4 cwt. of the finest bone-dust or fermented bones, and 15 cwt. of concentrated mineral superphosphate would form a compound containing 2 per cent. of ammonia, 23 per cent. of soluble phosphates, and 10 per cent. of bone phosphate, and costing less than £7 per ton.

A simple way in valuing a manure is to regard the 100 parts in the analysis as 100 tons. The amount of each ingredient is multiplied by the price per ton; all the products added together give the value of 100 tons; the result divided by 100 gives the value of 1 ton. Suppose a manure contains 1 per cent. of ammonia, 20 per cent. of biphosphate of lime, and 5·5 per cent. of phosphate of lime; then

	£	s.	d.
1 ton of ammonia, at £80	80	0	0
20 tons of biphosphate, at £30	600	0	0
5·5 tons of phosphate of lime, at £10.	55	0	0
	£735	0	0
Divided by 100, this gives per ton	£7	7	0

BUILDING CONSTRUCTION.—XIX.

STAIRCASES.

In our lessons on "Building Construction" we have touched on the methods usually adopted in the structure of walls and roofs, and the formation of every important part of a building, and we now come to staircases, by which we obtain the means of ascending and descending with ease and readiness from one floor of a building to another.

The rudiments of the staircase are to be found in the common ladder, formed of two parallel lengths of wood or a fir-tree sawn in half, connected by horizontal bars of wood or "rungs," from a foot to eighteen inches in length, and it may be remarked that nothing more than a ladder is frequently used even now for reaching a hay-loft or harness-room from the stable or coach-house below. When it was found that it was inconvenient and indeed almost impossible to ascend the ladder without grasping its sides by the hands, broad pieces of timber were substituted for the sides of the ladder, into which other broad pieces were inserted at a certain angle, so as to present a level surface when the whole contrivance was reared against a wall. This next step in the formation of a staircase may be readily recognised in the "steps" found in almost every household, and used for cleaning windows, walls, and a variety of other purposes. The transition from this to immovable flights of stairs, such as are now used in houses and buildings of every description, can be easily traced, and it is only necessary to point out that the staircase in course of time developed into an architectural feature of great beauty, as may be seen in many of our old English mansions and public buildings.

The construction of staircases is considered the highest branch of joinery, and the drawing connected with them requires much attention.

Staircases may be divided into—(1) Geometrical, or such as are supported by or against a wall; (2) Bracket stairs, or such as are built in an opening or well, with strings and newels, and are supported by landings and carriages, the brackets mitreing to the end of each riser; (3) Dog-legged stairs, which have no well-hole, the hand-rail of the progressive and the retrogressive flights falling in the same vertical plane.

The steps are fixed to *strings*, *newels*, and *carriages*; and the ends of the steps of the inferior kinds terminate only in the side of the string, without any "housing."

Fig. 182 is the plan, and Fig. 183 is the sectional elevation of a dog-legged staircase, with two-quarter winders—that is, the two spaces at A and B, instead of being used as a landing, are divided into winding steps. In the plan, *a* is the seat of the lower newel, and *g* is the seat of the upper newel. The dotted line represents the faces of the risers—that is, the upright portion of the steps; and the full lines are the plans of the surfaces of the steps, called the "tread." The edges of the steps are termed the "nosings."

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[*] I give these compounds the names by which they are familiarly known to agriculturists. Their strictly scientific designations have already been explained.

In the elevation, A is the lower and B the upper newel. The upper part of each is generally turned, but is here, for simplicity, rendered necessary by the small size of the illustration, drawn as if square. C and D are the lower and upper string-board, framed into the newel.

In the setting out of staircases a *storey rod*, R S, is used. This is a very necessary article, and consists of a rod or rule, of the gross height of the complete storey, or from the upper surface of the boards of the one floor to the under surface of those of the other. It is divided into as many equal parts as there are to be risers, and from these the heights of the steps are to be gauged. In the construction of dog-legged staircases, the first thing is to take the dimensions of the stair and the height of the storey, and to lay down a plan and section, representing all the newels and steps, upon a floor, to the full size, or certainly to as large a scale as possible. Then the situations of the carriages, pitching-pieces, long-bearers, and cross-bearers will be ascertained, as also the string-boards; and the quantity of room required by the stairs at nine inches tread and six inches rise, as the case may be, will determine whether there are to be quarter-paces, half-paces, one-quarter winders, or two-quarter winders.

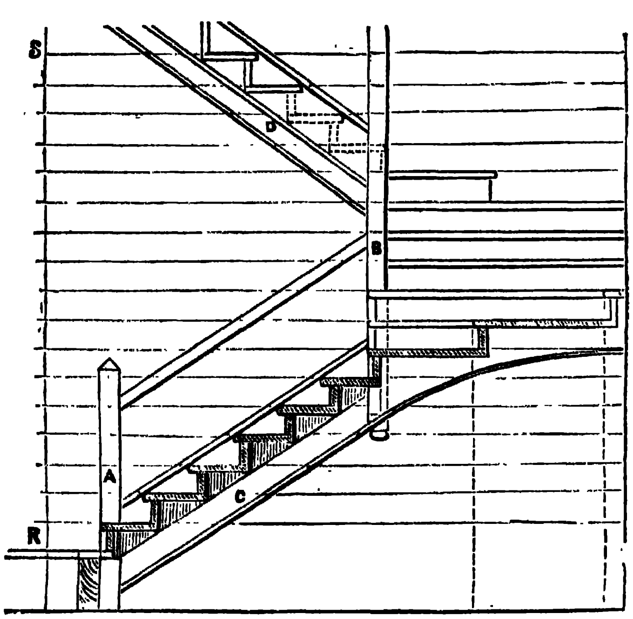
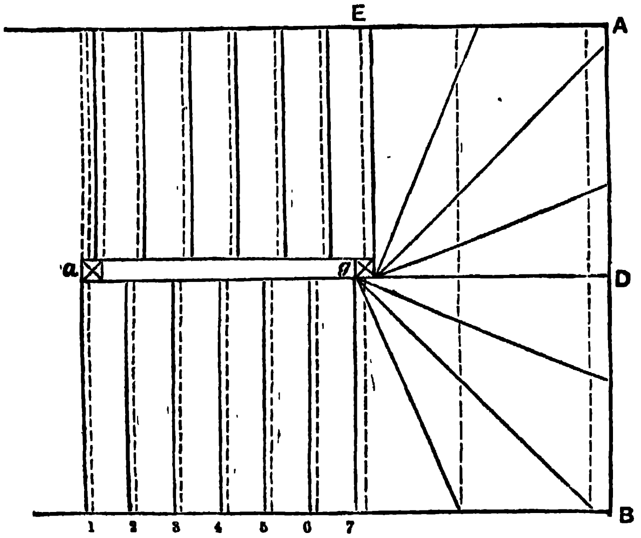


Fig. 183.



In drawing this example, or others of a similar character, having drawn the rectangle, which is the plan of the well in which the staircase is to be built, divide it longitudinally into two equal parts; on each side of the dividing line set off half the width of newels and hand-rail. This will leave the space on each side which is to be occupied by the stairs.

Draw lines *a* 1, 2, 3, 4, 5, 6, 7; produce line 7 across the width of the baluster, and produce the line of the baluster until it reaches D; the newel will then occupy the right angle formed at *g*. Complete the plan of the newel, and produce the line of its face to E.

It will be seen that E A is equal to the length of the stairs, and that this is the case with D B; but that A D and B 7 are increased beyond a square by the addition of the thickness of the newel *g*. This will be clearly understood on referring to the drawing.

Now divide this rectangle into the number of equal parts required for the winders, and draw the edges of these radiating from the angles of the newel. From E set off the upper flight of stairs, and thus complete the plan.

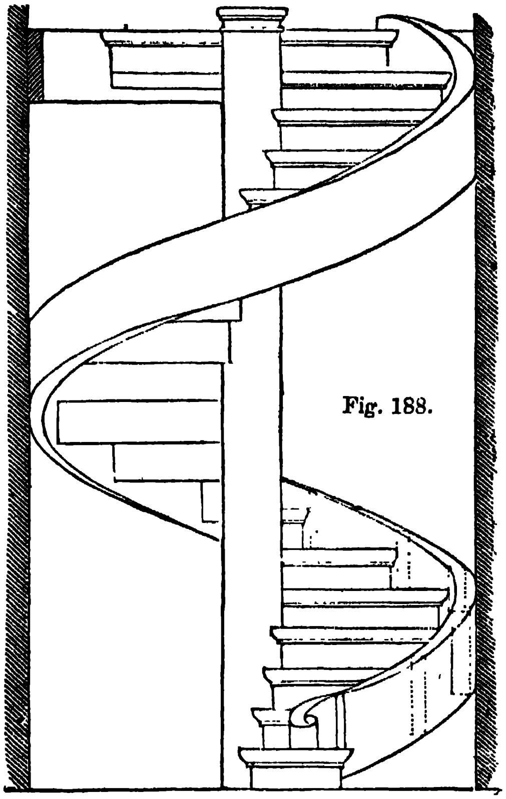


Fig. 188.

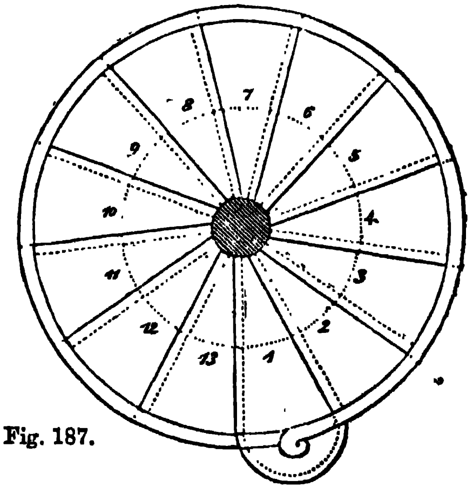


Fig. 187.

In commencing the elevation draw a ground-line, and project the line of the wall from A B in the plan. Draw the storey-rod, S R, and set off on it the heights required by the steps, and draw horizontals from each of these points; intersect these by perpendiculars drawn from 1, 2, 3, 4, 5, 6, 7 in the plan, and the points obtained by the intersections of these two sets of lines will give the edges of the stairs in the elevation. It will be seen that the points for the winders are obtained by drawing perpendiculars from the points where the edges of the winders in the plan cut the wall.

Next project the lower and upper newels, A and B, from *a* and *g* in the plan, and it will be seen that the lines of the hand-rail and string-board are parallel with a line drawn touching the edges of the stairs. Having drawn these, the arc forming the underneath line of the winders will complete the figure.

Fig. 184 is the plan and Fig. 185 is a section on the line A B of a staircase, with landing at half the height of the flight, and a narrow well between the ends of the stairs. The landing rests on three joists, *a*, *a*, *a*, which are stiffened by the cross-pieces, *b*, *b*.

The balusters and hand-rails are omitted in the section in order that the drawing may be rendered as simple as possible.

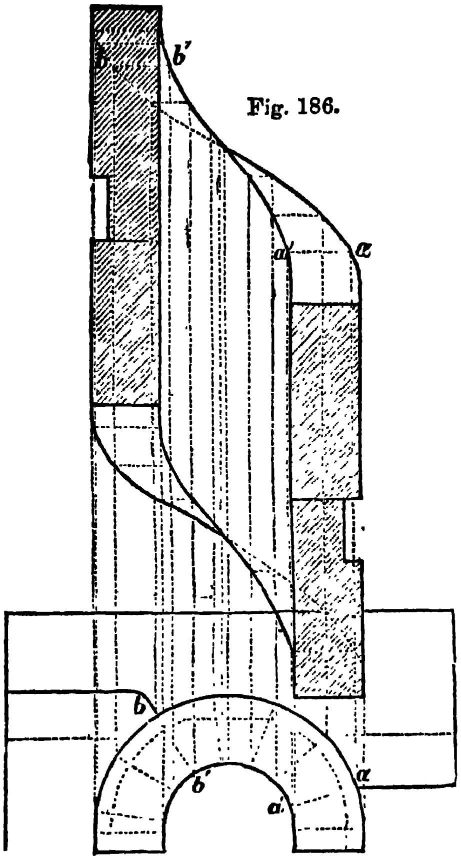


Fig. 186.

This study is to be worked on the same system as the last, the section being projected from the plan. It will be seen from the plan that the string-board turns at the end in the form of a semicircle; but although it turns *round* a semicircle, it must be remembered that it is at the same time *rising* to the next flight, and the curve it thus forms in the sectional elevation is a portion of a helix. In a drawing of the size of the example this curve might be drawn by the eye, but the power of doing this must be acquired by studying the true construction of the curve on a larger scale.

For the construction of the helix curve on which this figure is based, the student is referred to lessons on "Projection."

Fig. 186 represents the plan and elevation of the portion of the string-board under consideration, projected on a plane parallel to the steps in the example (Fig. 184).

Having drawn the outer semicircle, *a b*, and the inner semicircle, *a' b'*, divide either into any number of equal parts, and draw radii; divide the height which the curve is to ascend into the same number of equal parts, and draw horizontals.

Draw perpendiculars from the extremities of the radii, and their intersection with the horizontals will give the points through which the helices representing the winding round a semicircular space will be developed.

Fig. 187 is the plan and Fig. 188 is the elevation of a winding staircase with solid central newel. In the plan, the dotted lines represent the plans of the risers, and from these, therefore, the perpendicular edges of the stairs must be projected; whilst the nosings of the steps are to be projected from the full lines in the plan. The student who has worked the previous figures will not, it is presumed, require any further instructions in drawing this subject.

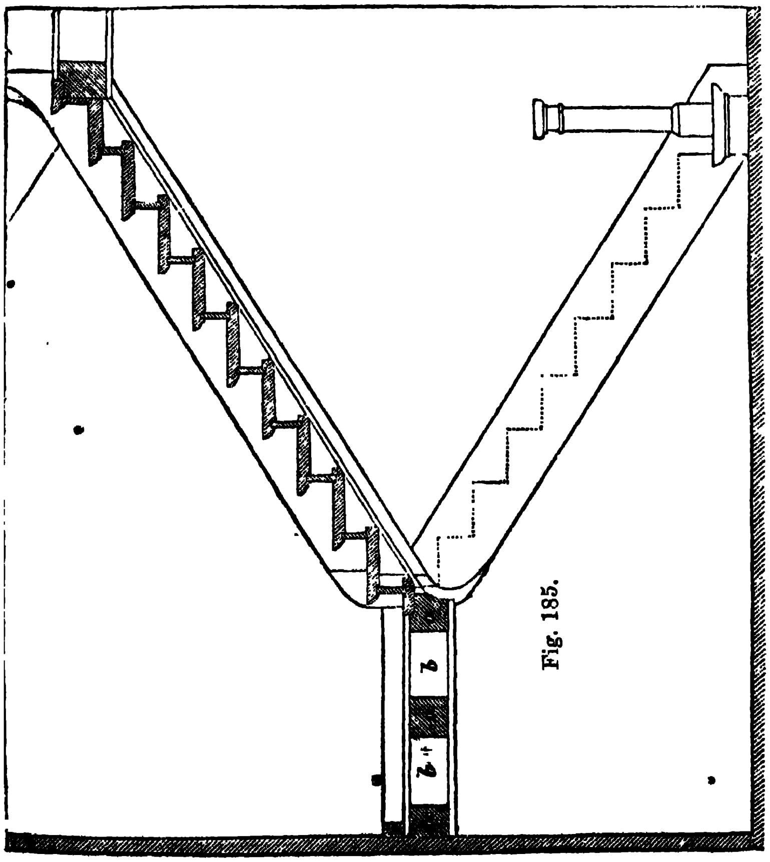


Fig. 185.

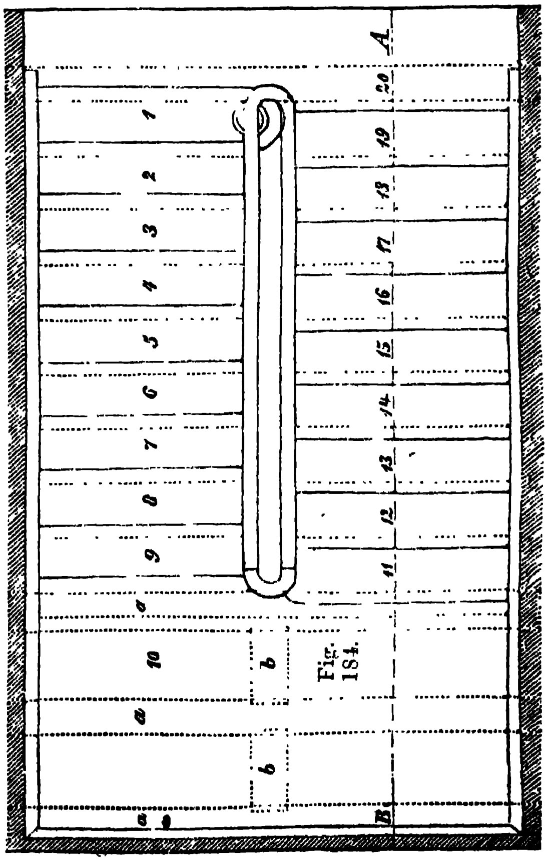


Fig. 184.

SANITARY ENGINEERING.—IV.

PRIVATE GAS-WORKS.

In our previous papers we have given some account of the method of gas manufacture for public companies—the comparative merits of different descriptions of burners—and in the last, on Photometry, of the manner in which comparison was instituted between various methods and materials for lighting purposes; quoting a few figures which clearly showed that gas was the cheapest of all. On its first introduction, at the begining of the present century, all gas-works were private, as there were no public companies; and now, after the lapse of a generation, the idea appears to be dawning upon the public mind, and to be generally received, that where the demand is sufficient in amount, and the other requisite facilities exist as to room, convenience, administration, etc., it is cheaper to *make your own gas* than to purchase it of a company. The process is in any case the same as generally described in our first paper upon the subject, and many engineering firms have recently turned their attention to the subject, with the view of producing sets of apparatus for the manufacture of gas in comparatively small quantities, as required for warehouses, for private mansions, or even for dwelling-houses. One firm alone has fitted up more than 600 sets of gas apparatus in various parts of the United Kingdom, and we propose to give the detail of one or two of these arrangements. One of the leading questions bearing upon the subject is, of course, that of price. Take London as an instance: 3s. 6d. per 1,000 cubic feet is an ordinary price for gas, and we may say without fear of contradiction, that it has been ascertained by repeated experiment, that under all ordinary circumstances the cost of the gas thus supplied, as far as the manufacture pure and simple is concerned, does not exceed 2s. 6d., thus leaving a margin of nearly 30 per cent. in favour of the man who makes his own gas. Where is the difference? In the immense outlay of capital already incurred by many of the companies in the earlier and less experienced stages of their existence, before the subject was so well understood as it is at the present time; in the large and expensive staff required for working and collecting; and above all, in the fearful per-centage of waste by leakage, condensation, etc., necessarily incurred in forcing the gas through lengths of piping of various sizes, extending over many miles of ground. The actual value of this last item is usually roughly calculated at 20 per cent.—that being the figure usually accepted—but probably a much larger figure would be nearer the truth.

In many country districts there is no public gas company within reach, and here the advantage, where the consumption warrants the necessary expenditure, of the erection of private gas-works is of course incontestable. Noblemen and gentlemen throughout the country are beginning to appreciate the advantage of the system, and we may instance some country seats of the highest class, where private gas-works are at the present time in course of erection or just completed: Bayham Abbey, for the Marquis of Camden, in the neighbourhood of Hawkhurst in Kent; Cliveden, the seat of the Marquis of Westminster, situate within a short distance of Maidenhead; Madresfield Court, near Worcester, for Earl Beauchamp; and the Grange, Alresford, for Lord Ashburton. Indeed, we have no doubt that in the course of a few years no country seat of any magnitude will be without its own gas-works, the advantages of economy and convenience being incontestable.

Coal is by no means the only material available for the manufacture of gas, though, of course, it is the most commonly employed. Peat has been utilised for the purpose, and by means of proper apparatus specially constructed, a gas of tolerable illuminating power has been obtained. In Bavaria, Professor Pethenkofer has introduced a process for the re-distillation of turf-tar, which has been extensively adopted; and in some parts of France, the refuse of manufactories, treated chemically with acid, has been profitably employed for the same purpose, thus utilising a material which had been previously considered utterly without value.

Petroleum is also a leading material among those from which gas may be made; the necessary apparatus being provided, gas can be made from it which possesses about three times the illuminating power of ordinary coal-gas, its cost, however, being greater in somewhat a like proportion; a special adaptation of burners, etc., is required for the consumption of these highly illuminating hydro-carbon gases, as if burnt by means of the ordinary media considerable waste is the result. We have heard of gas obtained from some of these oils which has a lighting power expressed by 30 candles, the gas of ordinary consumption being of about 15 candle-power. A reference to our paper on Photometry will explain what these figures mean, and how the results are ascertained and tabulated. Although these results have been experimentally obtained, commercially the question has not yet assumed sufficient practical development for us to recommend with confidence the adoption of this comparatively new process.

And now to give some idea of the facility that exists for the manufacture of gas by private firms: we may say that a complete set of gas apparatus may be procured for £50, which will supply the ordinary quantity required for 10 to 15 lights; they are made portable, of iron of course, and can be fixed in a space not exceeding 100 feet superficial, or 10 feet square. The first portion is the retort in which the coal is burnt, in a small apparatus like that in question producing about 40 cubic feet of gas from each charge. Iron cases, furnace-doors, shifting lids, hoops, etc., are all included; and the interior of the retort is generally lined with what are technically called fire-lumps—*i.e.*, bricks of a nature that will resist the action of intense heat, and which can be procured ready moulded to any required form. The next process is the condensing, washing, and purifying, the same for small quantities as for large, and all effected in a combined apparatus specially designed for the purpose. The last requirement is the little gas-holder, to contain from 100 to 150 cubic feet of gas, which is made of wrought plate-iron, provided with its small columns, balance weight, etc., as complete in its way as the huge gas-holders that form the distinguishing feature of all gas-works as seen from a distance.

The practical difficulty with these very small sets of apparatus is, of course, the attendance. If the proprietor have sufficient scientific knowledge to instruct a servant to attend to them, in which case he must thoroughly understand the detail of each portion himself, they may probably be introduced with advantage; but if this is not the case, as for so small a consumption it is not worth while to employ an engineer, probably the best course would be, if gas is so accessible, to obtain it from a public company. We have only described this very small apparatus in order to show into what detail it is possible to go upon the question.

The limit, we take it, of the point at which it becomes desirable from a commercial point of view to introduce private works, is that where the consumption is sufficient to warrant the engagement of one competent man who thoroughly understands the process, and can take entire charge of the gas-works; and to give an idea of the outlay required, we subjoin somewhat in detail the requirement for the supply of 1,000 burners for 8 hours; this we take to be about the limit probably necessary for a very large manufactory. We may mention that the details are taken from a specification that has been actually carried out; the portions resolve themselves, of course, as before, under the heads of (1) the retort, (2) the purifier, (3) the gasholder. The cost of the whole, including packing-cases, but exclusive of fixing, delivered in any part of England, may be taken at £1,200.

1. *The retort*, consisting of 18 cast-iron D-shaped retorts, each 7 feet long, 14″ × 12″, mouthpieces and lids for ditto; ears, cross-bars, and T-screws as required; 4 furnaces, of 12 bars each; furnace-doors, frames, etc., as required; 4 evaporating pans, sigh-boxes and covers; hydraulic main, 14″ diameter; ascension-pipes or stand-pipes and flange dip-pipes; tar-pipes to cistern.

2. *The purifier.*—Patent combined apparatus—Bower's in this case, though there are several others, forming in one vessel the condenser and scrubber; with 4 dry-lime purifiers; centre charge-valve and a double bypass-valve; 6 tiers of cast-iron sieves on wrought-iron T-bars; 5 wrought-iron lids, air-plugs, eyes and keeps; syphon boxes, cleaning doors; water spreader, etc. etc; small travelling crab, on girders; for moving various parts of apparatus.

3. *The gasholder*, 50 feet diameter by 15 feet deep at the sides, to contain 30,000 cubic feet; the crown of 15, the sides of 16 gauge thickness (this alludes to the ordinary method of measuring the thickness of sheet iron—viz., what is called the Birmingham wire gauge); and 6 cast-iron guide columns,

trussed girders, foundation plates, and all other necessary appurtenances.

It would, of course, be possible to describe all these matters in complete detail, but that would be beyond the limits of the space at our command, our object being only to give one or two instances of the way in which the commercial question has been elaborated, and the facility that exists of obtaining a complete set of apparatus for private gas-works. We should state, however, that the price quoted for the last set of apparatus includes no provision for setting or building work, but only expresses the first cost of the items to be procured; all these additional matters of expense will, therefore, be regulated by locality and similar circumstances; and it is of the utmost importance that any undertaking of the magnitude of that last described should be carried out under the superintendence of a thoroughly competent and responsible engineer; as otherwise disappointment and failure will be the almost inevitable result.

The two examples quoted may be taken as the extreme sizes, small and large, of private gas-works, the smaller being almost of an experimental character, and perhaps too diminutive for practical use; while the larger size has sufficient power to supply the gas required for public use in a town of from 2,000 to 3,000 inhabitants.

For private gas-works, strictly so called—*i.e.*, those attached to a mansion or a warehouse—perhaps 100 lights is a good average size to take, and without going again into the detail of the various appliances required, which vary only in size and capacity from those already described, we may say generally that the expense of such an apparatus, exclusive of brickwork and fixing, may be taken at £300. When attached to a gentleman's residence, the course usually taken is for the engineer who erects them to instruct one or more of the servants connected with the establishment—*e.g.*, a labourer or an under-gardener—in the details of the daily working; any question of construction or repairs being referred to the engineer. The price of the gas is regulated by the price of coals, and this by the district in which the house happens to be situated; the 2s. 6d. per thousand cubic feet quoted above should perhaps be taken as a minimum.

Good gas can be made from grease and kitchen waste, and a practical gas engineer of our acquaintance has lighted his own residence with gas made from these materials; but the scientific knowledge requisite for their successful manipulation being probably beyond the reach of the major portion of the public, we dismiss the matter with this passing notice.

MINING AND QUARRYING.—VII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

GENERAL DIFFUSION OF THE ORE—PRINCIPAL CENTRES OF WORKS—DIFFERENT KINDS OF ORE—ASSAYING—ANALYSIS.

No metal is so universally diffused in Nature, and that too in such abundant quantity, as iron. This is equally true when applied to almost every country of the globe, but it is our purpose here to confine our attention more particularly to the British Isles, and to those deposits within our borders which are of chief commercial value. At the present time (we do not wish to assert that it will always be so) many rich ores are practically valueless because they are unfavourably situated for reduction, and thus cannot compete with inferior ores which are in the immediate neighbourhood of the smelting works.

The low price of pig-iron, considering the quantity of material (ore, fuel, and limestone) required for its production, limits the trade almost entirely to those districts where all these three ingredients are abundant and cheap. There are some parts of the country, which will be spoken of presently, where iron-works are erected on other than Carboniferous strata; but this is an exception to the general rule, and even there they are favourably situated for bringing the fuel to the works at a very low price. There are, too, some large deposits of ore which are worked, and sent elsewhere to be smelted; but this can only be done advantageously in a few instances where the ore is rich and the cost of carriage is low.

The Weald of Sussex, for instance, contains a great deal of iron ore, and some 200 years ago or more it used to be smelted there; but the circumstances of the trade have altered so much that it cannot be done now. At that time the fuel employed was wood charcoal, but timber is now much too valuable to be used for such purposes, and the iron in those days was many times as dear as it is at present. Were the attempt made to revive the trade by using coal or coke, the cost of the fuel alone, burdened with a heavy carriage, would exceed the value of the iron produced.

The supply of ores is so prodigious that no fear can be entertained of a falling off, for centuries to come, which could affect the price of iron so as to render remunerative again works situated so unfavourably for economical working.

Let us consider some of the principal sources of supply, taking them according to their geographical distribution.

A very remarkable one, both for its extent and its novelty, is the Cleveland district of Yorkshire. It is only within the last twenty-five years that blast-furnaces have been erected for smelting these ores upon the spot—the commencement of an immense trade. The rock here belongs to the Lias formation. The "main seam," as it is termed, extends over an area of about 420 square miles, and varies in thickness in different parts from 3 to 18 feet. This one seam is estimated to contain nearly 5,000,000,000 tons of iron ore. In addition to this there is the "top seam," which covers a lesser area, having in many parts been carried away by denudation, and which is very irregular in thickness, varying from a few inches to 10 feet. These two seams consist of an earthy carbonate of iron, yielding from 10 to 36 per cent. of metal, but affording by their external appearance no indication of their mineral wealth. The ore rather resembles hardened clay, and contains the impressions of numerous shells, principally pecten and avicula, by which names different portions of the main seam are distinguished. The ores of low per-centage are neglected, as the supply of the richer is practically inexhaustible. There is also a still more limited but very valuable deposit, which is a magnetic oxide of iron, containing from 45 to 50 per cent. of metal. These ores are mined very much in the same way as a thick seam of coal would be. Headways are driven, 9 feet wide and 90 feet apart, from which, at intervals of 30 feet, "boards" are excavated 15 feet wide. By this system pillars are left, 90 feet long by 30 wide. When it becomes necessary to work the pillars, they are removed with a loss of only about 10 per cent. of their contents.

Another region, which was the scene of a great revolution in the iron trade in the early part of this century, is the iron district of Scotland which lies south of the Clyde. The coal-field of Ayrshire and Lanark contains a layer of ironstone, known, on account of its dark colour, by the name of "black band," which possesses most singular advantages for its economical working. It is a carbonate of iron, rich in metal, but containing also about 9 per cent. of coaly matter. The crude ore contains from 37 to 40 per cent. of iron, and the presence of coal in the ore enables the preliminary operation of roasting to be done without the addition of other fuel. Since the discovery of this ore the smelting of iron in Scotland has attained an enormous development, and the price of pig-iron has been very greatly reduced through the competition of the Scotch smelters.

In South Wales the beds of coal are almost always associated with bands of ironstone, and, accordingly, almost the whole of that large coal-field is studded with iron-works. It is the great centre for the manufacture of railway bars, which are shipped at the ports in the Bristol Channel to all quarters of the globe. The ore here consists mainly of an argillaceous carbonate, to which the general term of *clay-band* is given, though each layer of importance has its specific name. They are generally thin, but numerous, and contain about 25 to 30 per cent. of metal, with a large admixture of earthy matter, which gives them much of the appearance and colour of hardened clay. On account of this earthy admixture some of the richer ores, which will be spoken of presently, are often imported to mix with them. In the neighbourhood of Pontypool, however, the black band occurs, containing as much as 15 per cent. of carbonaceous matter, and yielding 30 per cent. of metal, an ore very advantageous to the smelter.

The midland counties yield large quantities of iron. So completely is the district between Dudley, Wolverhampton, and Birmingham occupied by this industry that agriculture is almost entirely neglected, and the whole surface of the country is black with coal-dust and iron slags; while at night it is suggestive of the infernal regions, being illuminated by the flames issuing from thousands of furnaces, and overhung with a lurid pall of smoke. This district has a special historic interest. It was here that Dudley, about the year 1620, first smelted iron with coal; but he thereby produced it at a much cheaper rate than his neighbours, so he and his inventions were not to be tolerated; and it was not till long afterwards, when wood was becoming so scarce that stringent measures had to be taken to prevent its annihilation, that the ironmasters betook themselves earnestly to mineral fuel. This was more than a whole century after the date of Dudley's patent. In our second paper we have spoken of the great deposit of coal in the South Staffordshire field. In some spots those of ironstone are scarcely less remarkable. The ores here consist of the argillaceous carbonate of iron—the prevailing description in all coal measures—and in some cases the beds attain a thickness of 27 feet. At Wordsley Bank, for instance, the Pennyearth beds are of that depth, and in addition there are 4 feet of "pins." At Brierley Hill these two beds together measure 27 feet. The peculiar names borne by different beds of "stone," which in this part of the country always means ironstone, are sometimes suggestive. "Pin" is a common term, indicative of the ore being in nodular concretions; the Pennyearth is so named because the bed is full of small flattened nodules somewhat resembling pennies. Throughout this district there are other beds of ironstone of varying thickness besides the two named, and the proprietors just select for working at each mine whichever may be the most convenient. The nodular character described above is a very ordinary feature of the beds in the coal measures, and many of these, being very thin, would never pay to work, were it not that other useful material is frequently obtained at the same time. Thus, on reference to Fig. 5 in page 33, where a section of the thick coal in Baremoor Colliery is given, it will be seen that there is a layer of ironstone lying immediately below the "herring coal," and again a second immediately below the "thick coal," and overlying the "first heathen coal." The latter is a very constant bed, varying from 2 to 8 or 9 feet thick, which has been very largely worked. It will be seen from this section that the ironstone and coal can both be got at the same time in these particular instances, so that they would be worth working even if the ironstone bed were very narrow. Again, at other times the iron ore will be close to a bed of fire-clay, and as this is an article of large consumption by the ironmasters, the two can often be profitably worked together. The bands of ironstone are generally very numerous, perhaps twelve to sixteen in number, but only those are regarded as of commercial value which are of sufficient size and richness to be worked for their own sake, or lie in association with the coal or fire-clay. The ores contain on an average about 33 per cent. of iron. When first wrought the argillaceous matrix of these nodules adheres to them, and could not be removed without considerable trouble and expense; but exposure to the action of the weather removes all this, and leaves the nodular concretions free.

To the west of this is an isolated district in which the iron manufacture has been carried on very successfully for a long term of years—Coalbrook Dale. This, again, as its name indicates, belongs to the Carboniferous period. Though the field is of limited area, the works established here possess no little historical interest, as it was here that Abraham Darby, the founder of the great firm that still bears his name, re-introduced the smelting of iron with pit-coal more than 150 years ago.

In North Staffordshire is another deposit of iron, also belonging to the Carboniferous formation, principally the usual earthy carbonates or clay band, containing about 35 per cent. of metal; but near Newcastle-under-Lyme the black band also occurs, containing, in addition, about 10 per cent. of free carbon.

The great coal-field of Derbyshire and Yorkshire also contains large deposits, exclusively of clay ironstone, and averaging about 30 per cent. of iron.

There are some of our most important coal-fields, however, which offer an exception to the rule which has been occupying our attention. Those of the north of England and Lancashire are deficient in these clay ironstones, which are so uniformly present in similar geological deposits in other parts of the kingdom. Not that these districts are without iron ores, but they are very limited in quantity, and of a different character from what has already been described.

In Northumberland and Durham the argillaceous iron ores do not occur in the Carboniferous rocks, but here and there we find spathic carbonates—beautifully crystallised ores—containing a large per-centage (from 38 even to 50) of metal. These are not in the coal measures themselves, but in the Carboniferous limestone, and if found in larger quantity would be of the greatest interest and value, as they yield a very superior iron, this kind of ore being usually free from phosphates and sulphates, which are difficult to separate, and highly injurious to the quality of the metal. An ore of similar character occurs in the Devonian beds of Somersetshire and Devonshire, and being very conveniently situated for shipment across the Bristol Channel to the iron districts of South Wales, these ores are extensively worked for the purpose of mixing with the Welsh.

The other deposits of iron ores of sufficient economic importance to call for special consideration also lie outside the Carboniferous epoch. The first that call for notice are the very remarkable deposits of red hæmatite (anhydrous ferric oxide, Fe_2O_3), which occur principally in Cumberland and the northern portion of Lancashire, and to some extent also in Glamorganshire. A curious feature connected with these is that they occur in large holes or pockets of the mountain limestone, though it is pretty evident that from a geological point of view they do not belong to that period. The red hæmatites commonly occur in crystalline masses radiating from the centre and rounded on the exterior surface, suggestive of the popular name, "kidney ore." At other times they are of an earthy character, but always leaving a very decided red mark; the rouge of silversmiths is, in fact, nothing else than this oxide ground fine. The hæmatites of Ulverstone and Cleator contain the extraordinary quantity of from 60 to 67 per cent. of metal, almost the only foreign matter in the ore being a little silica. Large works are erected for smelting these iron ores upon the spot, but great quantities are shipped also to South Wales and other places to mix with the inferior ores, as hæmatite produces iron of very superior quality. These ores, being found in large masses of irregular form and size, are worked more like a quarry. Near Cleator is a mass about 60 feet thick in some parts; and at other spots these deposits are so large that their thickness in depth is as yet unknown.

The only other description of ore of importance to the ironmaster, which has not yet been mentioned, is the brown hæmatite (hydrated ferric oxide, Fe_2O_3, + a variable quantity of water). This is very widely distributed, extending into the more recent strata, and is of considerable commercial value. It is generally more earthy in its character than the red, and produces a brown streak; this is often used as a pigment, under the name of ochre. The Forest of Dean supplies very large quantities, and, judging by the remains of ancient workings, it seems to date back, as an iron-producing district, as far as to the Roman occupation. Quite recently these ores have been turned to good account in Lincolnshire, Northamptonshire, and Oxfordshire, where they occur in considerable beds in the Oolite rocks. Increased facilities in bringing coals by rail has mainly contributed to the extension of the iron trade into these regions. The brown hæmatites vary considerably in the amount of metallic produce, being mixed with very variable quantities of earthy matter.

In addition to these there are many other compounds of iron in Nature, such as the common pyrites (sulphide of iron), arsenical pyrites or mispickel, which are not used in iron making, but are of value to the chemical manufacturer for the sulphur and arsenic they respectively contain.

Before commencing to reduce the ores it is important to know precisely their contents, because, in the first place, they may not yield the per-centage of metal which their appearance might lead one to expect; in the second, the nature and quantity of the earthy ingredients should be known, in order to determine the most suitable flux to be used; and, in the third, they may contain, in addition, some other ingredients, such as sulphur and phosphorus, which, even in small quantities, are deleterious. Any fresh deposit of ore is therefore subjected to assay, or analysis, before putting it into the blast-furnace.

The object of the assayer is to produce on a small scale what the smelter would realise on a larger one, from which it is easy to calculate the proportion of metal. The article which is required to be tested is put in the crucibles, which are placed on the fire-bars of the furnace, and packed all round with coke or anthracite broken small; the ash-pit below is open in front for the admission of air, and the chimney should not be less than thirty feet in height, so as to promote a powerful draught, with a damper for regulating it. The crucible is first brasqued, or lined with finely-pounded charcoal rammed hard, leaving only a small hole in the centre, sufficient to contain 100 grains of ore and the necessary flux. These are both pounded fine, and well mixed together. The flux varies according to the description of ore and the judgment of the assayer. The hæmatites will only need a little borax or flint glass. Ores containing silica, but deficient in lime or alumina, will require the addition of limestone or clay. Those, on the other hand, in which these prevail and the silica is wanting, are mixed with pounded quartz. Some need no flux at all. The charge having thus been put in the crucible, it is covered over with some more powdered charcoal, and then the lid is luted on with fire-clay, the crucible put into the furnace, and the fire got up, gently at first, lest the crucible should crack, but ultimately to a white heat, at which it is maintained for about a quarter of an hour. It is then allowed to cool down, the cover of the furnace is removed, and the crucible taken out. On opening it and removing the brasque, a solid button of iron should be found at the bottom, separate from the slag. If the metal is generally diffused through the mass, and only in a partially melted state, it indicates either that the temperature was insufficient or the flux unsuitable, and the experiment must be repeated. The button of iron is weighed, and that represents the per-centage of metal in the ore. The quality is commonly tested by hammering. If the button is flattened by the blow, the iron is good; but if it flies to pieces, and the fragments show a crystalline texture, it is of inferior quality. The colour and appearance of the slag will also tell the assayer whether he has appropriately selected and proportioned the ingredients of his flux, which is also a matter of much interest to the smelter. In order to save fuel and labour it is usual to have the furnace arranged to hold four crucibles, and so make that number of assays at the same time.

By the ordinary processes of chemical analysis every constituent of the ore can be ascertained quantitatively, and thus the per-centage of metal and the most appropriate fluxes can be easily deduced. As a specimen of the result to be thus attained the following is taken from the Reports of the Geological Survey as the analysis of an ore from Eston, in the Cleveland District:—

Protoxide of iron	39·92	per cent.
Peroxide „	3·60	„
Protoxide of manganese	0·95	„
Alumina	7·86	„
Lime	7·44	„
Magnesia	3·82	„
Potash	0·27	„
Carbonic acid	22·85	„
Silica	8·76	„
Sulphur	0·11	„
Phosphoric acid	1·86	„
Moisture	2·97	„

This will yield 33·62 per cent. of metallic iron.

BRICK AND TILE-MAKING.—II.

BY GILBERT R. REDGRAVE.

TERRA-COTTA, BRICKS AND TILES.

THE moulds used for terra-cotta are necessarily what are known as "piece-moulds," that is, they are composed of a series of slabs or pieces which fit together by means of checks or tallies, and form the sides of a sort of hollow box without a lid, the opening in which constitutes the back of the block, or that part which is not to be visible in the finished work. Having carefully fitted together and secured with string or cord the pieces of his mould, which should be as few in number as possible (we will not here describe the making of the mould from the model, as that is simply the work of any moulder or skilled plasterer), the workman rolls out some of the clay by his side into sheets, from one and a half inches to two inches thick, and by means of the open side forcibly introduces one of them into the mould. He then squeezes the clay carefully into all the crevices and depressions, which of course coincide with the projecting portions of the finished block. It needs considerable skill and dexterity to distribute the clay equally over the mould, and to fill out all the inequalities of enriched blocks—to force the clay fairly, in fact, into all the corners and crannies of the mould; and unless the clay is tolerably uniform in thickness throughout the work, all kinds of difficulties arise in the drying.

Having completely filled his mould, the workman, according to his judgment, introduces one or more stays or supports; these are webs of clay put in, in the form of partition walls, to support the main frame-work and to tie together the sides of the block. Some manufacturers then close up the back, leaving only a few small apertures for the exit of the moisture in drying and for the admission of the cement in setting. We think it, however, in all cases advisable to leave the back open, as the drying of the inner and outer surfaces of the clay then goes on more uniformly, and it becomes possible in fixing the terra-cotta to build the brickwork into the terra-cotta. In making a quantity of blocks of one pattern, the manufacturer invariably prepares a number of moulds, as, owing to the time the clay has to remain in the mould, the moulding operation is necessarily a very lengthy one. When a mould has been filled it is placed on a hot flue to dry, where, according to the nature of the clay and the size of the block, it may remain from two to six hours. In this time, owing to the absorption of the plaster and the shrinkage of the clay, in consequence of the loss of its water, the block leaves the sides of the mould, and readily permits of the removal of the several pieces. On quitting the mould the terra-cotta is far from being ready for firing, and requires a vast amount of scraping and trimming before it is set aside to dry; thus the junction of each piece of the mould produces a seam or "comb" on the block, which has to be very carefully removed; then, in spite of the utmost care in pulling away the sides of the mould, small pieces of clay frequently cleave to them and are broken off the block, and some chinks remain unfilled with clay. These places have to be repaired, and little irregularities on the surface have to be smoothed over, and all this patching and polishing throws great temptations in the way of the workman; thus it is that in a carefully modelled piece of terra-cotta it frequently happens that much of the crispness and spirit of the work is sponged and scraped away in this process of cleaning and repairing. After leaving the moulder the block is taken away to the drying loft or chamber, where it may remain for a week or a fortnight, according to the season and the state of the weather; and during this period it should be repeatedly turned, in order to prevent it from settling down in any one particular direction. The drying should not be carried on too rapidly or by means of artificial heat, as this tends to make the clay crack, and once cracked the block is worthless. The workman judges of the sufficiently dry state of the clay by its colour and by the weight of the block.

We may now suppose that a number of blocks have been made and are ready for firing, and we will attempt to give a brief description of the kilns. The kilns or ovens in general use are of three different kinds:—1. Circular in plan, with fire-places all round, varying from eight to twelve, or even sixteen in number. 2. Oblong, with fire-places at the sides and doors at either end; these kilns may have from eight to twenty fire-places or fire-holes. 3. Newcastle kilns, which are oblong in plan, with the fire-places at one end only, usually three in number. Of these kilns the latter are the least economical, that is, they require the most fuel—viz., about one ton of coal to one ton of goods; and the round kind are the best, as they are frequently fired with but little more than half this quantity. For all well and uniformly burnt terra-cotta the interior of the kiln should be "muffled"—*i.e.*, have an inner case or "muffle-lining" of fire-bricks, protecting the goods from direct contact with the flames and coal smoke. In some parts of the country the terra-cotta kilns, and even those in which the white glazed bricks are fired, have no muffle, but a kind of rude protection is built up in coarser goods round the finer articles to be burnt. In some places, too, they use a sort of half-muffle, called a "ring-wall," consisting of a lining reaching about half way up the kiln, which protects the ware from the first violence of the flame, and takes the place of the "bags" in an ordinary biscuit or gloss oven.

To describe adequately the various systems of firing would, we fear, lead us far beyond the limits of the present series of papers. We may state briefly that the two chief methods are respectively known as the up-draught and the down-draught, according to the manner in which the flame is conducted from the furnace through the kiln to the chimney. The ordinary up-draught is the old-fashioned plan; and the down-draught principle, which, when properly managed, saves a considerable amount of fuel, is of more recent introduction. The whole subject of pottery firing deserves careful study and investigation, as probably in no other manufactories, except in ironworks, does such a reckless waste of fuel take place as in potteries. The fire-places, or fire-holes, as they are very justly called, are rarely, if ever, supplied with fire-bars, and consist of mere rectangular brick chambers, with an orifice at the top for supplying the fuel, and an arched opening to the ash-pit, to get at the fire for the purpose of stirring it and withdrawing the ashes and clinkers. The fire is prevented from falling out of the fire-hole by means of a rough open wall of brickbats, called the "glut-bricks," the arch itself being called the "glut." The goods which are to be fired are introduced into the kiln through an opening on one side or one end of it, and are built up one on the top of the other from the floor to the roof. The floor is covered with a layer of crushed pottery or sand, and in a round kiln the heaviest and most massive objects are placed below, with the lighter or more hollow pieces above them. Great care and experience is, of course, required in filling a kiln and in stacking the goods, for unless the different objects are disposed with reference to the amount of heat they have to undergo, and the amount of weight they can safely bear, the contents of the kiln may be, and very often are, thrown into sad confusion when the heat comes to be applied.

When the kiln is full, and the smoking process is completed, the doorway is built up in bricks laid dry and plastered over with loamy clay, and the cracks and various openings are carefully stopped with the same material. Here and there, however, a brick is so arranged that it may be readily removed from time to time to observe the appearance of the interior of the kiln during the different stages of the firing. For many hours after the fires are lighted it is necessary to keep them very low, in order that the ware may be, as it is termed, "smoked." For this process it is also advisable to keep a current of air passing through the kiln, and therefore it is usual to leave the doorways and other inlets either partially or entirely open until the smoking is completed, and the goods are thoroughly dry. In the earlier part of the process dense volumes of steam are given off, which go to form the so-called "white smoke," and when this evolution has ceased, the fires are gradually made up until they are "brought up to the mouths," as it is called—*i.e.*, till the whole of the fire-chamber is full of fuel. The smoking may take, according to the nature of the contents of the kiln and their condition with respect to dryness when they were put in, from twenty-four to forty-eight hours, after which the "full firing" will take from sixty to ninety hours with thoroughly well-burnt fire-clay.

The treatment of the fires, the method of stoking, the management of the draught in the chimney, and a host of minor details in this stage of the manufacture of terra-cotta, require a vast deal more attention than they at present receive. The firing is, we are bound to confess—as usually practised at the present time—a very haphazard and random proceeding. It is so, even in the Potteries, with the finest kind of porcelain, and much more so with fire-clay goods and common ware. The truth of this matter is that manufacturers do not care to provide shelter round the kilns for the men, and thus, at night-time especially, the firemen are only too glad to avail themselves of any pretext for deserting their work. One mode of obtaining an hour or two's sleep, and of absenting themselves from the kilns, is by what is called "lumping" the fires—that is, filling them up with coal and piling a great heap of larger lumps over the mouth, so that as the fuel gradually burns away the lumps may drop down into the fire-hole. Of course this is a very wasteful and bad practice, as the piles of coal very often burn outside instead of inside the fire-chamber, or the fuel, instead of dropping down when wanted, "hangs in the mouth," and causes the fires to burn hollow.

A hollow fire is about the worst thing possible, as currents of cold or imperfectly heated air are thus allowed to enter the kiln, and may in a very short space of time undo the work of many hours, by cooling down the ware. There can be very little doubt, also, that unsteadiness in the mode of introducing the heat is fatal to the contents of the kiln, as alternate intervals of heating and rapid cooling can scarcely fail to crack the goods.

The firing of the terra-cotta is mostly conducted by means of "trials," in the same way as with fine pottery—that is, the fireman judges of the condition of the contents of the kiln by means of trial-pieces of ware, which he withdraws from time to time with an iron rod, through openings called "trial-holes," specially contrived for the purpose. These trials are of various forms, a very common one being a ring, cut off from the end of a drain-pipe, or a small basket, the aim in all cases being to enable the fireman to get hold of the piece readily. From three to four of these trials are placed at the top and bottom in each part or "quarter" of the kiln, and the workman is supposed, at the end of the process, to produce the trials he has withdrawn at each different period of the firing. These pieces, of course, indicate to him the relative condition of all parts of the kiln, and he can then manage his fires accordingly. Thus, he may have to "push" certain fires and slacken others, in order to "bring up the quarters" all alike, or he may have to "work for the top" or bottom if he finds any important difference in the state of his top and bottom trials. The theory of trials is all very well, but an experienced workman goes more by the look of the goods through the "spy-holes" than by anything else. Moreover, the trials alone do not constitute a reliable guide, especially when the kiln is old and "leaky," or full of vents and cracks. A new kiln will frequently "fire up" in half the time an old one will, and thus show a vast saving in fuel. We should like here to have described some of the new inventions for kilns and furnaces; but this would, we fear, take up more space than we can spare.

After the last stoking the fires are allowed to burn gradually down, and in twenty-four hours' time the door is opened and the cold air permitted to enter the kiln. This should not be done too soon, as it might cause the ware to "fly" or crack. When terra-cotta is wanted in a hurry it is often got out quite hot, and before the kiln is thoroughly cool a new lot of goods has been put in and the fires are again lighted. It will readily be understood that this alternate expansion and contraction is most prejudicial to the stability of the kilns, and it is necessary to build them most solidly and to tie them together with iron hoops or bands. However carefully this is done they soon begin to split open and crack, and the crown of the kiln, which consists, of course, of a brick dome, sooner or later falls in or has to be taken down. The repair of his kilns is consequently one of the most expensive items incurred by the manufacturer.

The colour of fire-clay terra-cotta, when well burned, is, as we have observed, a dark buff, and to our mind terra-cotta can hardly be too much fired. Those blocks which are under-burnt or are too pale in colour to build in properly with the other work may readily be fired again and made to take a deeper tint.

We have thus glanced at the various stages in the manufacture of fire-clay terra-cotta, and we may, in concluding this portion of our subject, make a few remarks on other varieties of this material.

Most manufacturers can, if desired, furnish a red terra-cotta, and many firms will, if necessary, give us a blue or a green colour at a slight extra cost. We cannot but regard the white or buff ware as the only true terra-cotta, in spite of the fact that almost all the ancient ware was red in colour. We have given our reasons for maintaining that the red clays will not stand any great degree of heat, and because in the dry climates of Greece and Italy the red ware has lasted well, we must not assume that it will do so in our own damp climate. We are convinced that there is no more durable material than well-burnt fire-clay, and if a red colour is necessary it should be obtained by mixing colouring matter with the clay. White terra-cotta forms an excellent dressing for a red brick building, and appears to be structurally the true method of decorating it. Terra-cotta and stone-work should never be used together, and red terra-cotta should not be used with a white brick building. Terra-cotta can, if it is required, be made to take a coloured enamel-glaze, and it is then known as "della robbia" ware, or, in a humbler form, as glazed bricks, which are now made in various colours by several manufacturers in the neighbourhood of Leeds. Lastly, terra-cotta is admirably suited for receiving a glaze, technically known as "salt glaze," and clay in this form is well known to us in the shape of the numberless kinds of so-called "sanitary goods." This glaze is produced by throwing on the fires at the end of the "firing up" a few handfuls of salt, which is decomposed on the surface of the hot ware in the kiln, and forms a glaze of silicate of soda with the evolution of hydrochloric acid.

OBJECT DRAWING.—IV.

FIG. 21.—This is a triangular prism, the end of which is parallel to the picture-plane.

The end, which in this instance is an equilateral triangle, is to be drawn first; and from its angles, *a*, *b*, *c*, lines are to be drawn to the point of sight; the line *d e* will then complete the lower side of the prism.

Now it is clear that *d e* is the base of the triangle forming the distant end of the prism; and knowing that this triangle is equilateral, having merely been moved backward from the foreground, but the direction of its plane not having been changed, it would be easy to draw an equilateral triangle on *d e* without any further trouble; but this would not teach the principle of drawing the figure if the triangle were not equilateral; and it is, therefore, desirable to proceed in the method from which such instruction is to be derived.

From *c* draw the perpendicular *c f*, and from *f* draw a line to the point of sight, which will pass through *d e* in *g*. At *g* draw a perpendicular, to correspond with that drawn on *f*. From *c* draw a line to the point of sight, meeting the perpendicular *g* in *h*. From *h* draw *h d* and *h e*, which will complete the view.

Fig. 21

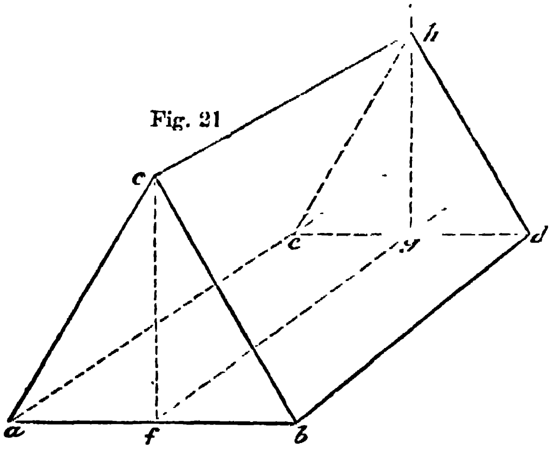


Fig. 22.

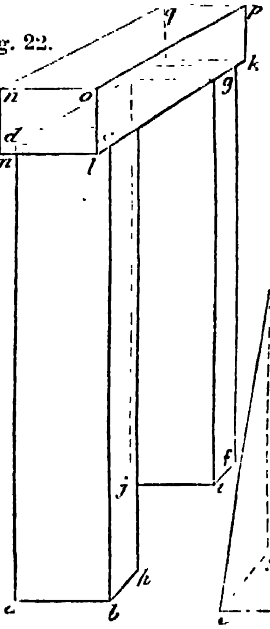


Fig. 23.

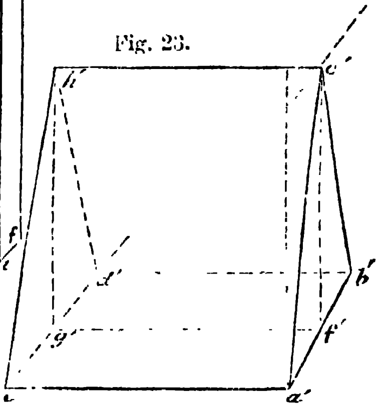


Fig. 22 is made up of three models of equal size, and forms a simple doorway at right angles to the plane of the picture.

This is another application of the models used in the previous lesson. Draw, in the first place, the side of the one upright which is parallel to the spectator—viz., *a b c d*. From *b* and *c* draw lines to the point of sight, and erect the perpendicular *f g*. Draw a line from *d* to the point of sight, and from *g* draw a line parallel to *c d*, which will complete the view of this part of the model, rendered as a mere slab. Now draw the perpendiculars *h* and *i*, and from *a* draw a line to the point of sight. From *i* draw a line (*i j*) parallel to *a b*, and at *j* erect a perpendicular. This will give the inner side of the distant upright. Now produce the line *c g* until it projects sufficiently beyond the perpendiculars, bearing in mind that as all lengths are diminished by distance, the length from *g* to *k* must be less than *c* to *l*, although these would be equal in the model. Then draw the rectangle *l m n o*, representing the end of the horizontal block. From *o* draw a line to the point of sight. At *k* draw a perpendicular, which will give *p*, the point at which the distant horizontal is to be drawn. Now from *n* draw a line to the point of sight, cutting the horizontal in *q*, and the object will thus be completed.

Fig. 23 is another triangular prism.

In commencing this figure, sketch the plan *a′ b′ d′ e′*, remembering that *a′ b′*, which represents the base of the end, being now at right angles to the picture, will converge to the point of sight. Between *a′* and *b′* set off the point *f*, making *a′ f* slightly longer than *f′ b′*, and at *f* erect a perpendicular. Erect another perpendicular at *a′*, and mark on it *a″*, equal to the real height of the triangle. From *a″* draw a line to the point of sight, cutting the perpendicular *f* in *c*. Draw *a′ c′* and *c′ b′*, which will complete the triangle.

From *f′* draw the horizontal *f′ g′*. At *g′* erect a perpendicular, and from *c′* draw a horizontal intersecting this perpendicular in *h′*. Draw *h′ e′* and *h′ d′*, which will complete the object.

The group forming Fig. 24 consists of a cube standing on two square slabs which form steps around it, the cube being covered by a pyramid.

Draw the rectangle *a b d c* representing the vertical edge of the lower slab. From *c* and *d* draw lines to the point of sight, and complete the view in the manner with which the student will now have become acquainted.

Now the lower slab forms a step around the second one equal in width to its height; therefore, having drawn diagonals in the upper surface of the slab, set off *c e* and *d f* equal to *a c*, and from *e* and *f* draw lines to the point of sight, cutting the diagonals in *g*, *h* and two distant points, as shown in Fig. 2 (page 4). The quadrilateral formed by joining these points will be the plan of the second slab.

At *g* and *h* erect perpendiculars, which, as the second slab stands a little back from the picture-plane, will be drawn rather shorter than *a c*. Draw a horizontal line for the edge, and complete the object as before.

Set off, on the edge of this slab, the width which it projects beyond the cube, which, as in the previous case, is the same as the height of the slab. Draw lines to the point of sight, cutting the diagonals, and this will give the plan of the cube and pyramid, which may now be completed in the manner shown in the figure.

The object which is shown in Fig. 25 is the one which has already been drawn in another position in Fig. 22. The front elevation is now parallel to the picture. This view is so extremely simple that the student may fairly be expected to draw it without further instructions.

In the previous lessons the objects have been so placed, that their front and back surfaces have been parallel to the picture.

Under such circumstances, the sides alluded to retain their original *shape*, however much they may be diminished in *size* by being moved into the distance.

This has been exemplified in page 132, in which the front of the cube in Fig. 13 is a square like that of Fig. 11, but reduced in size, in consequence of its being placed back in the picture; and similarly, the side of the distant upright in Fig. 22 is similar in shape to the side *a b*, but is diminished for the same reason.

It now becomes necessary to consider the method of drawing objects when their sides are placed at different angles to the picture-plane.

In order that the student may fully comprehend the exact difference between the positions of the objects now to be considered, his attention is called to Figs. 26 and 27 in the following pages.

Fig. 26 is the plan of a cube, placed so that its front and back are parallel to the picture, which is supposed to stand on the line A B. This position has already been explained in reference to Fig. 1 (page 4), and several such subjects have been subsequently worked out.

Fig. 27 shows the plan of the same object when placed so that neither side is parallel to the picture-plane, A B; only the angle *a* is really in the foreground, the other surfaces receding from it. In the present plan it will be seen that the object is placed at equal angles—that is, the side standing on *a b* recedes at the same angle as does the side standing on *a c*, and it will be seen from the plan that the side *c d* is parallel to *a b*, and *b d* to *a c*.

We will now proceed to draw the cube so placed.

Let *a e* (Fig. 28), be the vertical edge of the cube which is nearest to the spectator, and resting on the point *a* in the plan. Now we know that the edge *a d* in the plan and the corresponding edge of the top of the cube are *horizontal*; but we have seen that horizontal lines when not parallel to the picture converge to a point in the distance—that point being the point of sight when the lines in the object are at right angles to the picture; but the line *a d* and the corresponding edge of the upper surface, *e d′*, are, as has been shown by the plan, *not* at right *angles* to the picture, and therefore they converge (*not* to the point of sight, but) to a point in the horizontal line called the vanishing-point. The lines *a b* and *e b′* converge in a similar manner to a point on the left side.

Care must be taken that these lines are not drawn up too obliquely, which makes the sketch appear as if the object were tilted up from the back. It must be understood that the vanishing-points need not necessarily be on the paper, nor need the lines be drawn entirely to them. A little observation and practice will enable the student to judge of the amount of inclination required, and to sketch the object with tolerable correctness. The rules for finding the exact position of the vanishing-points, etc., do not fall within the province of these lessons, but are fully treated of and practically worked out in the lessons in "Practical Perspective."

The student must use his judgment, too, in determining the positions of the perpendiculars *b b′* and *d d′*, bearing in mind that the width of the sides will vary according as the object is moved to the right or left, and that both sides will be the same when the object is placed immediately opposite the eye.

The following principle will now be found useful to the student:—

All lines which in the object are parallel to each other, vanish in the same point.

Now it has already been shown in the plan that *b d* is parallel to *a c*, and that *c d* is parallel to *a b*.

Therefore, according to the above principle, draw a line from *e* to the right-hand vanishing-point VP^r, to which *a d* and *b c* have already been drawn; and from *e* draw a line to VP^l, to which the lines *a b* and *d c* converge. The object being drawn as if transparent, it will be seen that the same rule is carried out in relation to the distant lines of the base of the cube.

Fig. 29 is a view of the same cube when placed above the level of the eye of the spectator, and the lines therefore run *down* to the vanishing-points on the horizontal line.

Fig. 30 is an upright block which, being higher than the spectator, passes above the horizontal line; and thus, although the lines from the nearest angle at the bottom are drawn upward, those from the top incline downwards.

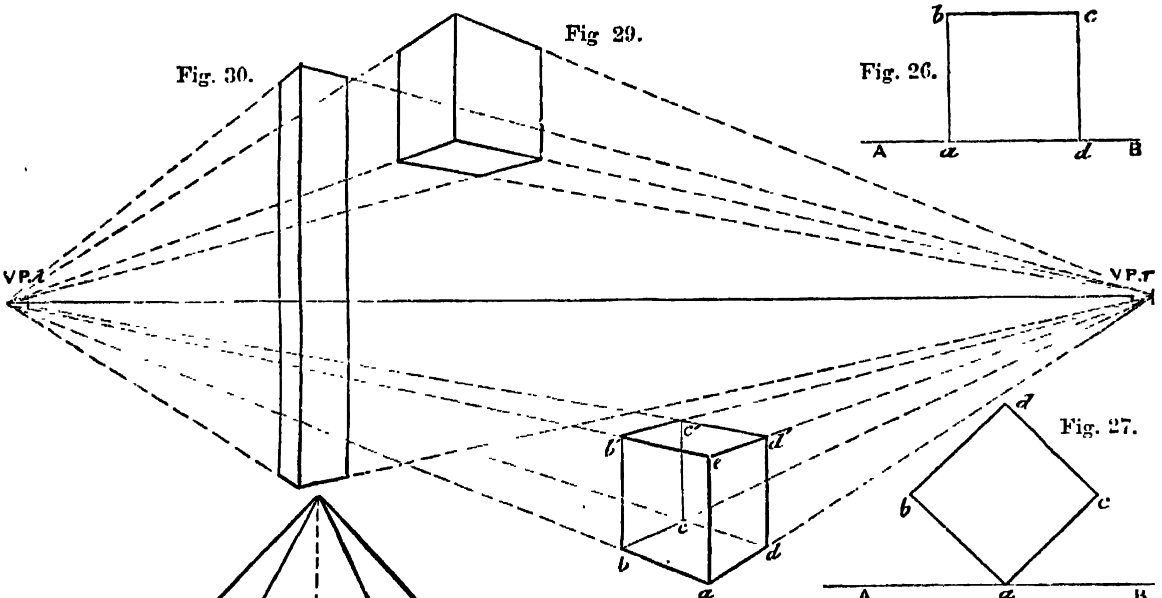


Fig. 30.

Fig. 29.

Fig. 26.

Fig. 27.

Fig. 28.

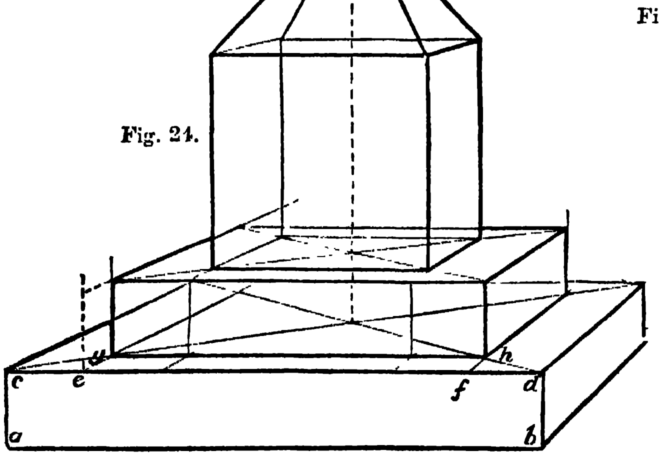


Fig. 24.

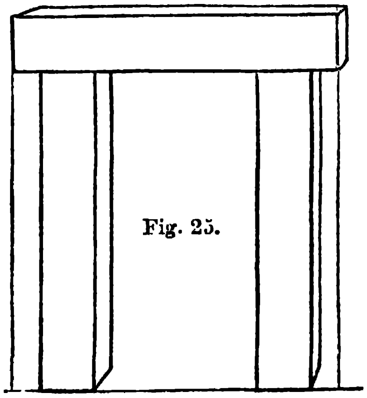


Fig. 25.

OPTICAL INSTRUMENTS.—IX.

BY SAMUEL HIGHLEY, F.G.S., ETC.

SPECTACLE-FRAMES (*continued*).

I shall now proceed to describe and figure the various forms of spectacle-frames; but before entering on a detailed description of these, I may remind the reader that at page 112 of Vol. I. of The Technical Educator I have described and figured (Figs. 4, 5) two forms of "protectors" used for shielding the eyes from dust or glare of light, about which it will be unnecessary to say anything further here.

Hand Reading-glasses are large convex lenses, of various sizes, mounted in circular metal frames, fitted to ebony or ivory handles. These glasses are sometimes cut into an oblong shape to reduce their weight. Such glasses are often used when the sight begins to dim, for reading small print by lamplight. Even with glasses of large diameter, it will be noticed, as a rule, only one eye is employed; but as persons usually read with the greatest comfort when the glass is held at such a distance from eye and object that the rays proceed in a parallel direction, not much mischief accrues. Nevertheless, their proper office is for magnifying small objects of art, natural history, etc.

Eye-glasses are single lenses, which may be simply drilled, as in Fig. 17, or mounted in light rims of horn, tortoiseshell, steel, gold, or plated metal, as in Figs. 18, 19, to suit the taste or pocket of the purchaser, and are suspended from the neck by a plaited silken cord, or they may be fitted with a universal joint, on a stem that can be screwed and clamped on to the front of a hat, as shown in Fig. 20, to meet the requirements of shooting and riding. The occasional use of single glasses on distant objects can do no harm to the eye; but their constant use on near objects tends to alter the focus of the eye thus armed with extra power (which eye is usually the one on the right side); while, moreover, the other eye tends to deteriorate from want of use, and may become amblyopic. When the necessity for optical assistance is really felt, it is preferable at once to adopt double eye-glasses or spectacles.

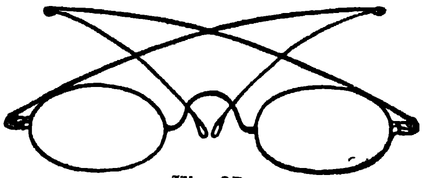


Fig. 27.

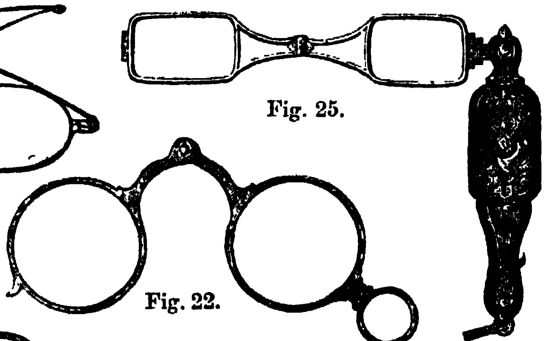


Fig. 25.

Fig. 22.

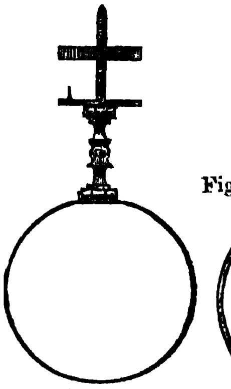


Fig. 20.

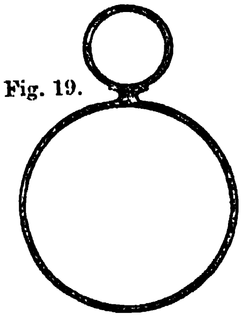


Fig. 19.

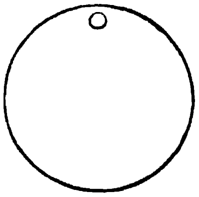


Fig. 17.

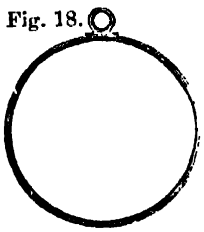


Fig. 18.

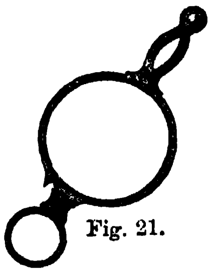


Fig. 21.

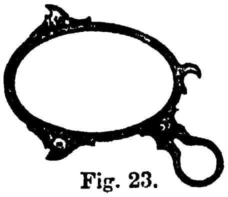


Fig. 23.

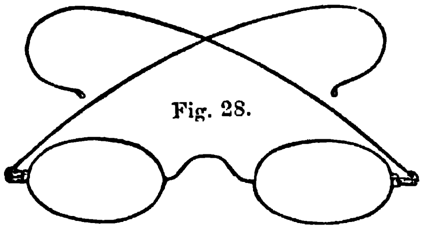


Fig. 28.

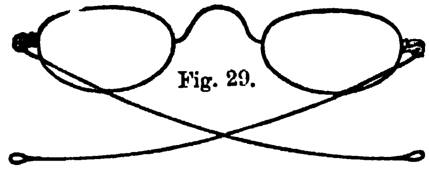


Fig. 29.

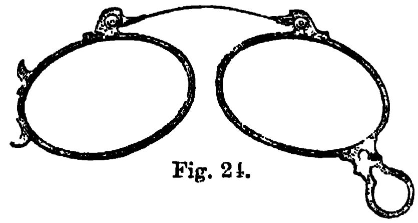


Fig. 24.

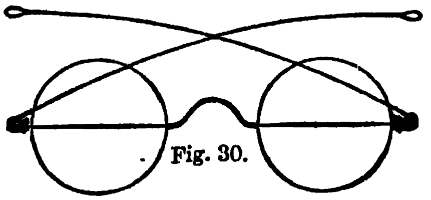


Fig. 30.

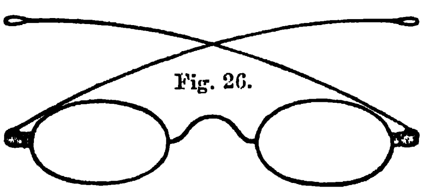


Fig. 26.

Dr. W. C. Wells, in his work on "Vision," quotes the experience of the late eminent optician, George Adams:—"The fact is this, that he does not know a *short-sighted person* who has had occasion to increase the depth of his glasses if he began to use them in the form of *spectacles*; whereas he can recollect several instances where those have been obliged to change their *concave* glasses repeatedly for others of higher powers who had been accustomed to apply them to *one eye only*."

Usually it is myopics (*and pretended myopics*) who take to single eye-glasses. Every-day experience teaches us that objects appear considerably clearer and brighter when seen with both eyes than they do when seen with one only.

Hand-folders are glasses so mounted in horn, tortoiseshell, or metal frames that they close over each other, as shown in Figs. 21, 22, 23, 24, and so occupy less space than spectacles, and are very conveniently carried in a waistcoat pocket.

The French term these *pinces nez*, as they pinch the nose either by the folding joint, as shown in Fig. 22, or by the action of a steel spring that unites the lenses by hinge-joints, as shown in Fig. 24.

An elegant form of the double eye-glass, especially suited for ladies, is the *lorgnon* (Fig. 25), usually, but erroneously, called a *lorgnette*, which term the French apply to an opera-glass, whether it be large or small.

The objection to all such frames is that it is mere haphazard whether the lenses are centered with the axes of the eyes of the wearer, or are held parallel to the eyes, so that the strain and irritation that may be set up in the organ of vision counterbalances the advantages derived from their apparent convenient form.

Spectacle Frames.—The usual form of oval-fronted frames with single sides is shown in Fig. 26, and the "turn-pin frames," with double sides working on a pivot, in Fig. 27.

Invisible Flexible Frames are made with very light wire sides, curved to fit behind the ears, and the fronts, instead of being made with rims into which the lenses fit, are buried in grooves cut in the flat edges of the glasses. This form (shown in Fig. 28) is much affected by clergymen, and is one well suited for the short-sighted when walking or riding.

Pantoscopic Frames are made with the rims flattened at the tops, as shown in Fig. 29, and set obliquely to the eye, so as to be in the best position for the long-sighted to look upon near work, while it enables them to gaze upon distant objects unobstructedly.

Divided Spectacles are made with "round-eye fronts," and two lenses of different focus are neatly cut across their centres, and then carefully adjusted in their frames, so that the halves of long focal length are in the upper, and the halves of shorter focal length in the lower segment. Such glasses have been found very useful to artists who have to look rapidly from the distant object to the near canvas on which they are depicting it. Both Sir Joshua Reynolds and Benjamin West employed such spectacles, which are certainly preferable to the clumsy and heavy arrangement where two pairs of glasses were made to turn in combination or separate, by means of a hinged joint. The divided spectacle is shown in Fig. 30. Benjamin West for many years wore such an arrangement, with the upper halves of 30 inches and the lower of 12 inches focus; but some years before his death, which was at the age of ninety, the lower halves were changed to a focus of 8 inches. His glasses were 1½ inches in diameter. The philosopher Franklin was slightly myopic, and had little power of accommodation, and for looking at a distance he had need of negative, for seeing near objects he had need of positive glasses. He therefore devised a pair of divided spectacles, and combined the two halves so that the concave occupied the upper and the convex the lower portion of the frame, and thus provided very well for his want of accommodative power. Such spectacles have been called "Franklin's glasses." Of late years the French have combined in one lens, what Franklin attained by cutting and combining two lenses, by grinding the upper and lower halves of different foci, so that, according to an oculist's order, opticians can supply lenses of different positive or negative focus in the two halves, or positive focus above and negative below of any given foci. Such lenses are termed "*verres à double foyer.*"

It is indispensable that these should be accurately adjusted at the proper height before the eyes, so that in looking at a distance the rays may fall upon the upper, and in looking at near objects through the lower part of the organ of vision. The pupils must not be opposite the line that intersects the upper and lower lens, or confusion of vision will result. The proper set of the frames, in ascertaining this point, must be determined more by moving the eyes than by moving the head.

While speaking of spectacles used for near and distant objects, I may note the necessity for checking the foolish practice of some long-sighted people, who, while wearing convex glasses suited for viewing near objects, also employ them for viewing distant objects. As such improper use of spectacles will bring about loss of the accommodative power of the eyes, they should remove them when looking at distant objects, or adopt the pantoscopic form. When speaking of spectacles for eyes of different foci, at page 355, I gave the practice of Donders, also followed by many other oculists, which is founded on the belief that if in such cases we supply lenses of different foci to suit each eye, though we make the range of accommodation for each eye more equal, *the magnitude* of the images in each would be unequal, and the result unsatisfactory.

It is curious that so great an authority on the optics of the eye should have arrived at such a conclusion, for it has been experimentally demonstrated by Mr. Charles Heisch, of the Middlesex Hospital, by an instrument specially constructed for the purpose, that if a patient, *having eyes of different foci*, be accurately fitted with glasses of *different foci*, exactly suited for each eye, then the two images may be made of *equal magnitude*, but the converse will result if glasses of *equal foci* be employed for each eye.

When the difference is slight this method of treatment may be disregarded, if accommodation be good; but even with such a difference, say, of a focus of 14 inches for one eye and 12 inches for the other, much good results from suiting both eyes properly, according to the dictates of optical laws.

Spectacle glasses must be kept clean and bright, and should be wiped with the softest and cleanest of wash-leather, or fine soft tissue paper. When not in use the frames should be kept in well-shaped spectacle-cases, to guard as much as possible against the lenses being scratched. Should they be thus injured or otherwise dimmed they should be changed immediately. When reading or working by night the light should fall on the object, while the eyes are shaded, and a glaring, flickering, or unsteady flame should be carefully avoided.

In concluding this long series of articles on the human eye and the optical treatment of its defects, I have endeavoured to give a careful digest of modern practice, especially of that followed by German oculists, to whom we are indebted for many methodical investigations.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XIV.—HENRY BELL.

BY JAMES GRANT.

"INVENTIONS born before their time," says the ex-Emperor Napoleon III., "must necessarily remain useless until the level of the common intellect rises to comprehend them." The truth of this maxim is well illustrated by the failures of those who in past times have thought of steam locomotion as possible by land and sea: such as when Senor Blasco de Garay made his attempt in the time of Charles V.; when Denis Papin made a similar essay at Cassel, in 1707; and when the unfortunate James Taylor, of whom a memoir was given in THE TECHNICAL EDUCATOR (Vol. I., p. 147), first sought to apply this novel power to inland navigation on Dalswinton Loch and the Forth and Clyde Canal, towards the close of the last century.

Henry Bell, who had inspected the vessel constructed by the latter, as she lay rotting and forgotten at Carron, and who foresaw the vast uses to which such a ship could be applied, and was eventually the first successful adapter of steam to the purposes of navigation in Europe, was born on the 7th of April, 1767, in the little straggling village of Torphichen, in a wooded and sequestered part of Linlithgowshire. The central feature of the hamlet is the ruin of the fortified church of the Scottish Knights of St. John. He was sprung from a race of sober, hardy, and industrious mechanics, being the fifth son of Patrick Bell and his wife Margaret Easton, whose ancestors, for many generations, had been well known in West Lothian as ingenious millwrights and builders; and some of whom had constructed harbours and bridges not only in Scotland, but in other parts of the United Kingdom. As usual with the children of the humbler classes in Scotland, Henry Bell received a plain education at the parish school, and in 1780 was apprenticed to a stonemason.

This employment he would seem to have disliked; and three years after he commenced a new apprenticeship with his uncle, as a millwright, in the vicinity of Torphichen. In 1787, his term being complete, he went to Borrowstownness, on the Forth, to learn the art of ship-modelling, and engaged himself as a journeyman with Mr. James Inglis, engineer, at Bell's Hill, with a view to completing his knowledge in mechanics. After a time he went to London, where he found employment under the eminent Mr. Rennie, whose line of business afforded Bell ample opportunities of acquiring a great practical knowledge in the higher branches of engineering; but being of a restless nature, like many other men of genius, he returned soon again to Scotland, and worked for many years at Glasgow industriously as a simple house-carpenter, and in 1797 was enrolled as a member of the corporation of wrights in that city.

Bell was not without ambition, and it was his greatest desire to contract for some of the public works in Glasgow; but being totally without capital or wealthy friends, he never succeeded in having his hopes realised in that way. "His mind was a chaos of extraordinary projects," says a writer, who seems to hint that he lacked the power of concentration; "the most of these, from his want of scientific calculation, he never could carry into practice. Owing to an imperfection in even his mechanical skill, he scarcely ever made one part of a model to suit the rest, so that many designs, after a great deal of pains and expense, were successively abandoned."

The idea of propelling vessels by steam, on Taylor's principle, was undoubtedly one that took very early possession of his mind.

"In 1800," he writes (twelve years after Taylor's little steamer paddled across Dalswinton Loch), "I applied to Lord Melville, on purpose to show his lordship and the other members of the Admiralty the practicability and great utility of applying steam to the propulsion of vessels against winds and tides, and every obstruction on rivers and seas, where there was depth of water. After duly thinking over the plan, the lords of that great establishment were of opinion that it would be of *no value* in promoting transmarine navigation."

It is gratifying to think that the hero of the Nile and Trafalgar thought otherwise.

"My lords," said he, emphatically, when Bell brought forward his project again in 1803, "if you do not adopt Mr. Bell's scheme other nations will, and in the end vex every vein of this empire. *It will succeed*, and you should encourage Mr. Bell."

Events have shown how truly the great admiral spoke; and he might have proved a firm friend and patron of the humble projector, but two years later saw him lying dead in the cabin of the *Victory*.

Still constructing models and struggling with circumstances, Bell, who had married, removed from Glasgow, in 1808, to Helensburgh, a watering-place on the Clyde, begun about thirty years before by Sir James Colquhoun, Bart., of Luss. There his wife undertook the superintendence of the public baths, and at the same time kept the principal hotel; while "he continued to prosecute his favourite scheme, without much regard to the ordinary affairs of the world."

Nelson's prophecy speedily became true, when in 1807, on the 3rd of October, Mr. Fulton, who had also inspected Taylor's steamer at Carron, launched the first river-steamer in America on the waters of the Hudson, and regularly corresponded with Bell concerning its progress and development.

In 1811 the latter began to construct a vessel of 30 tons burden, 40 feet long, 10 feet 6 inches beam, with an engine of 3 horse-power, and on a plan that was entirely his own. This craft he named the *Comet*, that year having been remarkable for the appearance of a brilliant one. She was built by Messrs. John Wood and Co., and made her trial trip on the 18th of January, 1812, when she sailed triumphantly from Glasgow down the Clyde to Greenock making five miles an hour against a head wind.

By the midsummer of that year Bell advertised that his wonderful new ship would ply upon the Clyde thrice weekly from Glasgow, sailing "by the powers of air, wind, and steam;" and September saw the voyages extending to Oban and to Fort William, at the mouth of Loch Eil, four days being the time required for going and returning.

Bell had constructed the steam-engine with his own hands; he had encountered, like poor Taylor, those innumerable and indescribable difficulties incident to the career of the unfriended inventor. His success was now, however, complete; and though many others were now encouraged to embark their capital in similar undertakings of a much greater nature, Bell did not realise personally any solid advantages from his discovery. He had, however, the satisfaction, accorded to few, of living to see his invention universally adopted over all the waters of the globe. The Clyde, which first enjoyed the advantages of steam-navigation in Britain, became the great seat for building ships of that kind, and in that respect still maintains its equality with, if not superiority over, any other port in the world.

"Clyde-built ships, with Glasgow engines," says Dr. Chambers, "make the voyage between Liverpool and New York in ten days. Steamboat building and marine-engine making received their first powerful impulse from the solution of the problem of ocean steam navigation. From tables constructed by Dr. Strong, from returns furnished to him by the various shipbuilders and engineers in Glasgow, Dumbarton, Greenock, and Port Glasgow, it appears that during seven years, from 1846 to 1852, there were constructed at Glasgow and in its neighbourhood, 123 vessels, of which 1 was of wood, 122 of iron, 80 paddle, and 43 screw; consisting of 200 wooden tonnage, 70,441 iron tonnage, 6,610 horse-power engines for wooden hulls, 22,539 horse-power engines for iron hulls, and 4,720 horse-power engines for vessels not being built on the Clyde. During the same period there were constructed in Dumbarton 58 vessels, all of iron, 20 being for paddles, and 38 for screws, and having a tonnage of 29,761; and during the last three years of the same period, 3,615 horse-power engines were made there for iron hulls, and 200 horse-power engines for vessels not built on the Clyde. During the same period, from 1846 to 1852, there were constructed at Greenock and Port Glasgow 66 steam-vessels, of which 13 were of wood and 53 of iron; 41 paddle and 25 screw, consisting of 18,131 wood tonnage and 29,071 iron tonnage; 129 horse-power engines for wooden hulls, 5,439 horse-power engines for iron hulls, and 4,514 horse-power engines for vessels not built on the Clyde. For the whole ports on the Clyde alone, the steam-vessels built and the marine engines made between 1846 and 1852 were as follow:—Wood hulls, 14; iron hulls, 233; in all, 247—of these 114 were paddles and 106 screws. The tonnage of the wooden steamers amounts to 18,331; of the iron 129,273. The engine horse-power in wood hulls was 6,739; in iron hulls it was 31,593: while there was of engine horse-power for vessels not constructed on the Clyde, 9,434; making a grand total of 247 steamers, amounting to 147,604 tons, and of engines, 47,766 horse-power."

Since 1852 the increase has been correspondingly great; and as a sample of the number and tonnage of vessels ordered from private firms, the following may be noted in 1868 alone:—Messrs. Napier, four iron-clads (10,636 tons, and 2,140 horse-power); Messrs. Caird and Co., six steamers, each of 3,000 tons and 600 horse-power; Messrs. Denny, two composite gun-boats, one armour-clad, and five screw-steamers (10,520 tons, and 1,970 horse-power); Messrs. Randolph and Co., eight screw-steamers, two iron ships, and two lighters (10,510 tons, and 1,310 horse-power); Messrs. Thomson, three screw-steamers, one paddle, and one gunboat for Government, and one iron ship (7,000 tons, and 1,020 horse-power).

It was in 1813 that a steamer was first placed on the Thames; but the projector, an Irishman, had to succumb to the privileges of the Thames watermen.

But to return to the subject of our memoir. Notwithstanding that Glasgow owed so much of her greatness to his success, he reaped but little more than honour, and was permitted to approach the confines of old age in very straitened circumstances. The engine of the *Comet*, which was made by Bell's order, and at which Mr. David Napier worked as an engineer, making the boiler chiefly, after lying in the sea for many years after the *Comet* was wrecked in one of the dangerous channels of the West Highlands, was brought to Glasgow, and in 1840 was exhibited as a kind of curiosity to the members of the British Association. Each wheel had four paddles, of the malt-shovel form.

Touched by the unrewarded years of Bell, the late Dr. Cleland, an eminent statistical writer, with a few other benevolent individuals, commenced a subscription in his behalf, and induced the River Clyde Trustees to grant him an annuity of £100, which was continued to his widow; and this was deemed but a humble acknowledgment of the value of his great invention on the part of those guardians of a river whose annual revenue was increased mainly by the impulse given to its trade by steam navigation from £6,676 in 1810 to £76,000 in 1852.

Henry Bell died in his sixty-third year, at the Baths in Helensburgh, on the 14th of March, 1830, and was buried in the parish churchyard of Row, in Dumbartonshire.

On the picturesque rock of Dunglass, in the Clyde, and rising above the ivied ruins of the old castle of that name, towers a great square obelisk to the memory of Henry Bell. It is a conspicuous object to all vessels traversing the river; but no stone marks the resting-place of him who first conceived that project which Bell achieved—Taylor, who launched the first little steamer on the Loch of Dalswinton. Her engine—"the parent engine of steam navigation"—is now preserved in the Commissioners of Patents' Museum at South Kensington.

In concluding this notice of Henry Bell, it ought to be remembered that some sixty years before the time when he sought the patronage of the great Lord Nelson, the idea of propelling vessels by steam had occurred to an Englishman named Hulls. This idea he gave to the world in a small pamphlet, entitled "A Description of a Newly-invented Machine for Carrying Vessels or Ships out of or into any Harbour, Port, or River, against Wind and Tide, or in Calm; for which His Majesty has granted Letters Patent, for the sole benefit of the Author, for the space of Fourteen Years. By Jonathan Hulls. London: Printed for the Author, 1737. Price Sixpence."

To this publication is prefixed a diagram, showing a large, decked vessel, without masts or rigging of any kind, a short funnel, without stays, smoking amidships; three fly-wheels working on deck, but half sunk through it, and two other fly-wheels, with bands over them, working astern; between the latter revolves a screw, having six spokes, with square shovel ends or paddles, and she tows a two-decker man-of-war. A copy of this publication is preserved in the British Museum, and has been referred to in Robert Stuart's "Anecdotes of the Steam-engine;" but until the days of Taylor and Bell the idea of a steam-vessel went completely to sleep, for it is inseparable from the course of events that every one who has rendered a great service to mankind by any new invention, the objects of which are misconceived or misunderstood, has had to complain of the neglect of his own generation and time. The real recompense in such circumstances is the consciousness of doing one's duty. Even Fulton, the introducer of the steamboat in American waters, had the mortification, at first, of being treated as an idle projector, whose schemes would be ruinous to himself and useless to the world. He was treated as a visionary, and "the new water-vehicle" was ever an object of ridicule till launched. "Their language," he says, "was uniformly that of a sneer or scorn. The loud laugh often arose at my expense; the dry jest; the miscalculation of losses and expenditure; the dull but endless repetition of the 'Fulton folly.' Never did a single encouraging remark, a bright hope, or a warm wish cross my path!" But Fulton, like Henry Bell, was fated to rise superior to the disappointments which usually beset the authors of great and important inventions.

PRACTICAL PERSPECTIVE.—XII.

We now continue the subject that was commenced in the last lesson, repeating the entire illustration to save students the trouble of reference.

Fig. 58 is a view of the same prism when the triangular end is at right angles, and consequently the edges of the prism are parallel to the plane of the picture.

Having fixed the position of the point A, draw a line from A to the centre of the picture.

From A set off A B, equal to the base of the triangle, and from B draw a line to the point of distance, cutting the line A C in B′.

A B′ will represent the perspective appearance of the base of the triangle.

From A or B mark off F, the middle point between A and B, and from F draw a line to the point of distance, cutting the line A B′ in F′.

At F′ erect a perpendicular.

Now it will be clear that the apex of the triangle will be situated upon this line, and the next step must be to determine its exact position.

At A erect a perpendicular, and mark on it the real altitude of the triangle (whether equilateral or otherwise) A C′.

From C′ draw a line to the centre of the picture, cutting the perpendicular F′ in C″, which point will be the apex required.

Join A C″ and B′ C″, which will complete the perspective view of the end of the prism at right angles to the plane of the picture.

We now proceed to project the prism itself, the length of which is parallel to the plane of the picture.

From A set off A D, the real length of the prism, and from D draw a line to the centre of the picture.

From B′ draw a line parallel to A D, cutting the line drawn from D to the centre of the picture in the point E.

A D E B′ will then be the perspective view of the plan of the prism in this position.

From F′ draw a horizontal line, cutting D E in G, and at G erect a perpendicular.

From C″ draw a horizontal, cutting the perpendicular in H.

Draw D H and E H, which will complete the figure.

Let us next consider the object when standing on its triangular end, in which position, of course, all the edges of the prism will be vertical (Fig. 59).

We will in this elementary study suppose the object to stand at equal angles—that is, in such a manner that the sides facing the spectator recede equally from the picture-plane, in which case the third side, A B′ E D, which in both the previous figures formed the plan, will be upright, and parallel to the plane of the picture.

Now the student who has followed the lessons thus far will know that for the projection of objects in angular perspective it is necessary, in the first case, to find the station-point, the vanishing and measuring points, and he will, no doubt, remember that the distance of the station-point from the centre of the picture is equal to that of the points of distance, and therefore, a perpendicular having been drawn at C, the distance C PD set off upon it from C will give S, the point of station.

At S draw a horizontal line, and construct the angles at which the sides of the object recede from the picture. In the present case it will be clear that as the sides of the object itself are at 60° to each other, and as the prism is to be placed at equal angles, there will be three angles of 60° each meeting at S.

Produce the sides of the middle angle of these three until they meet the horizontal line, and thus give the vanishing-points.

It will be remembered that, to find the measuring-points, the length from the vanishing-points to the station-point is set off on the horizontal line, and when this is done in the present instance it will be seen that the measuring-points become coincident with the vanishing-points, since the figure contained by the two vanishing-points and the station-point is an equilateral triangle. It will, of course, be understood that this could only occur when the object is placed at equal angles.

Having, then, found the necessary points, and having fixed the position of the nearest angle of the object at C′, draw lines from this point to the vanishing-points.

From C′ set off on the picture-line C′ A and C′ D, equal to the real side of the equilateral triangle; and from A and B draw lines to the measuring-points, cutting the lines drawn from C′ to the vanishing-points in A′ and B′.

Join A′ B′ by a line which, if the work be correctly done thus far, will be horizontal; but this would not be the case if the object did not stand at equal angles. At C′ draw C′ H, equal to the real length of the prism (A D in the two previous figures); from H draw lines to the vanishing-points; and from A′ and B′ draw perpendiculars, cutting these in D and E.

Join D E, which will complete the projection; and it will be seen that, as required, the distant side A′ B′ E D will be parallel to the plane of the picture.

Exercise 46.

The scale is ¼ inch to the foot; height of spectator, 6 feet; distance, 18 feet. The subject is a prism, the end of which is an equilateral triangle of 4 feet side, and the length of which is 8 feet. The same dimensions and object are used in Exercises 47 and 48.

Put into perspective the prism when lying with its end parallel to the picture-plane, and at 6 feet within the picture, and 5 feet on the left of the spectator.

Exercise 47.

Put into perspective the same prism when lying at 9 feet within the picture, its edges being parallel to the picture-plane, and its triangular end being 5 feet on the right of the spectator

Exercise 48.

Put into perspective the same prism when standing on one of its triangular ends, one of its long edges being at 2 feet on the right of the spectator, and the side of the prism on the right of that edge receding at 50° from the picture.

Exercise 49.

Give the perspective view of the object when standing at the same angles as that of the last exercise, but its nearest edge to be at 5 feet on the left of the spectator, and 8 feet within the picture.

Exercise 50.

Put into perspective the same prism when lying on one of its sides, so that its triangular end is vertical, and recedes from the picture at 40°, the nearest angle being at 4 feet on the left of the spectator, and 8 feet within the picture.

In the next study the scale we have adopted is ¼ inch to the foot, the height of the spectator being 5 feet, and the distance 16 feet.

The subject of the study is a pyramid, the base of which is an equilateral triangle of 4 feet side, and the height of which is 4 feet.

In Fig. 60 A B C′ is the plan of this pyramid, from which it will be seen that it is placed at angles of 50° and 70° to the picture-plane.

Therefore at the station-point construct angles of 50° and 70°, and obtain the vanishing and measuring points in the usual manner. It will be observed that neither the station-point, the first measuring-point, nor the points of distance, are shown in this diagram.

In commencing Fig. 61, mark off the position of the point A at 2 feet on the right of the spectator, and draw lines from A to the vanishing-points.

From A set off B and C', equal to the length of the sides A B and A C' in the plan. From these points draw lines to the measuring-points, cutting the lines drawn to the vanishing-points in B' and C'. Join B' and C', and the triangle thus formed will be the general outline of the plan.

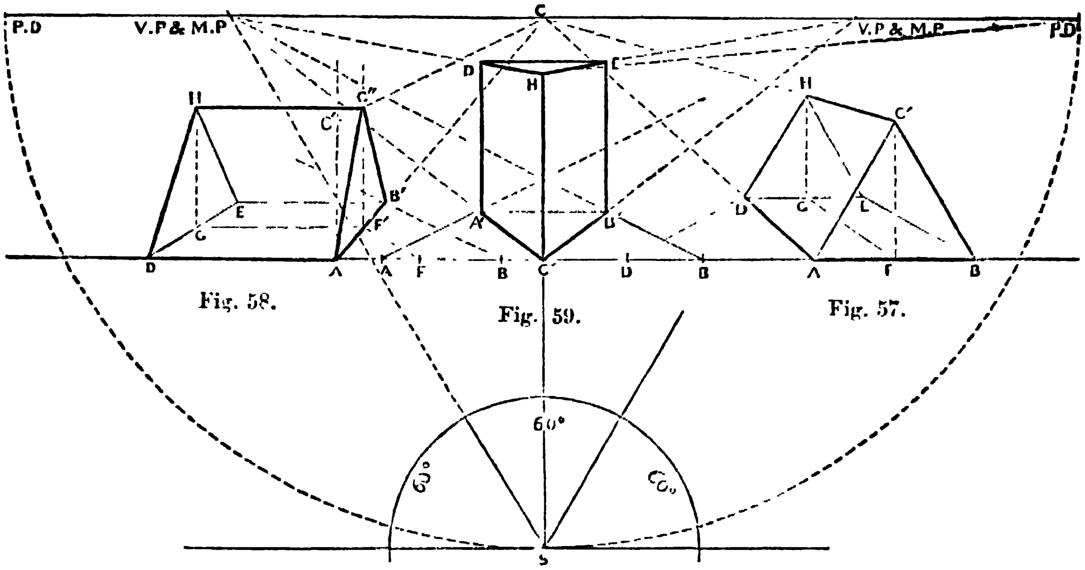


Fig. 58.

Fig. 59.

Fig. 57.

It is now necessary to find the centre of this figure, and to do this we must return to the plan (Fig. 60).

Draw lines bisecting the angles of the triangle A B C'. These will form plans of the edges of the pyramid, and meeting in the centre, give the plan of the apex.

Produce these lines until they meet the sides of the triangle in the points *a*, *b*, and *c*.

Set off these points between A B' and A C' (Fig. 61) on the picture-line—viz., *a* and *b*; and from them draw lines to the vanishing-points, cutting A B' and A C' in *a'* and *b'*.

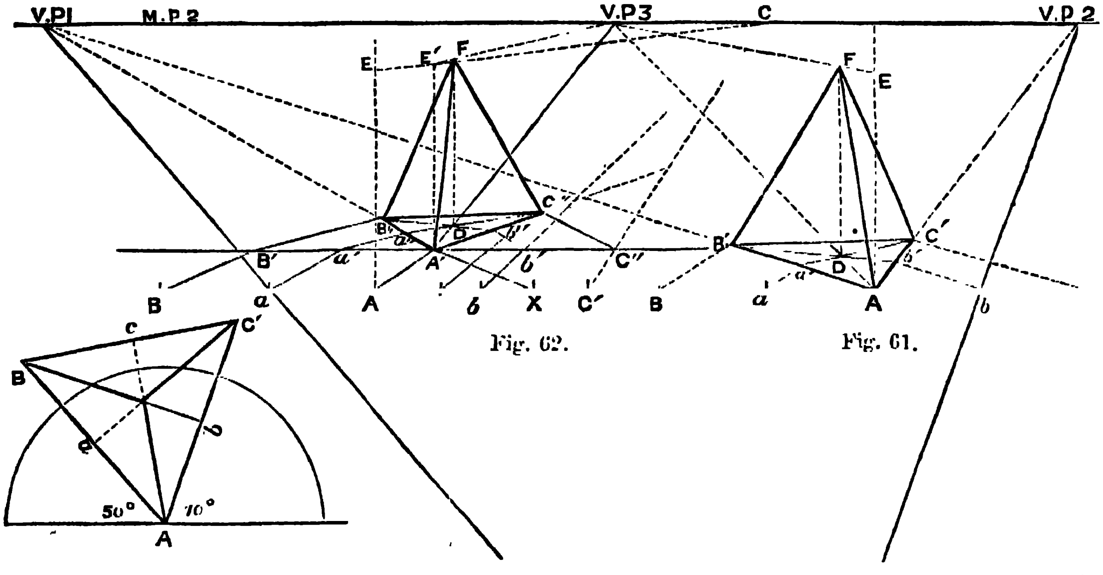


Fig. 62.

Fig. 61.

Fig. 60.

From *a'* and *b'* draw lines to the opposite angles of the plan B' and C'. These intersecting will give D, the centre of the plan.

From A draw a line through D, and produce it to cut the horizontal line in VP3. This would be the vanishing-point for a plane resting on A D.

Now, to find the perspective height, erect a perpendicular at A, and mark on it E, the real height of the pyramid, in this case 4 feet.

At D erect a perpendicular of indefinite height.

From E draw a line to VP3, cutting the perpendicular D in F. Then F is the apex of the pyramid.

Draw A F, B' F, and C' F, and the projection will be completed.

We now proceed (Fig. 62) to put this object into perspective when placed 3 feet back in the picture.

Let A be the point at which the angle of the pyramid would be situated if it were in the foreground.

From A draw a line to the centre of the picture; from A set off A X, representing the real distance which the object is to be placed backward.

From X draw a line to the point of distance (not shown in the plate), cutting A C in A', which will be the required position of the point; and through A' draw the movable base-line.

Now from A set off A B and A C', equal to the length of the sides; also, between them, the points *a* and *b*.

From B and C' and from *a* and *b* draw lines to the centre of the picture, cutting the movable base-line in B, C'', *a'*, and *b'*. The working is now precisely similar to that of the last figure, excepting the mode of finding the height; in order, therefore, that this may be made clear, the process will, as far as is required, be repeated.

From A' draw lines to the vanishing-points, which, as the object stands at the same angles as the last subject, are those already used in Fig. 61.

From B' and C'' on the movable base-line draw lines to the measuring-points, cutting the lines drawn from A' to the vanishing-points in B'' and C''. Join these points, thus completing the general outline of the plan.

Next draw lines from a' and b' to the measuring-points, cutting A′ B″ and A′ C″ in a'' and b''.

From a'' and b'' draw lines to the opposite angles of the plan; and these intersecting will give the centre, D.

From A′ draw a line through this centre, meeting the horizontal line in VP3, being the same point to which the corresponding line in Fig. 61 vanishes, because the planes, standing on these lines in both objects, would be parallel to each other, although the one were in the foreground and the other in the distance, so long as the angles they make in the picture-plane are the same.

It now remains to find the height. To do this, erect a perpendicular at A, and mark off on it A E, equal to the real height of the pyramid.

At A′ erect a perpendicular, and from E draw a line to the centre of the picture, cutting this in E′. The height A E is thus removed 3 feet backward in a track at right angles to the plane of the picture.

Now on D, the centre of the plan, erect a perpendicular, and from E′ draw a line to VP3, cutting it in F, which will give the apex of the pyramid.

Draw A′ F, B″F, and C″F, which will complete the figure.

EXERCISE 51.

All the conditions as to scale, height, and distance of the spectator being the same as in the last plate,

Put into perspective a pyramid, the base of which is an equilateral triangle of 5 feet side, the height being 7 feet, when its nearest angle is at 8 feet on the left of the spectator, and when one side of the plan is at 65° to the picture.

EXERCISE 52.

Give the perspective projection of the same object when at a distance (at pleasure) on the right of the spectator, and 8 feet within the picture.

EXERCISE 53.

Scale, $\frac{1}{2}$ inch to the foot. Height of spectator, 5 feet; distance, 15 feet.

Put into perspective a pyramid, the base of which is a *square* of 4 feet side, and the height of which is 7 feet, when one angle is in the immediate foreground, the sides of the plan receding at 50° and 40°.

EXERCISE 54.

Scale, $\frac{1}{4}$ inch to the foot. Height of spectator, 6 feet; distance, 18 feet.

There is a cube of 4 feet side, on which rests a square pyramid, the base of which coincides with the top of the cube, and the height of which is 5 feet.

Put this object into perspective when standing at 6 feet on the right of the spectator, and 8 feet within the picture.

CHEMISTRY APPLIED TO THE ARTS.—XII.

BY GEORGE GLADSTONE, F.C.S.

ALUM.

ALUM, in a chemical sense, has a wider range of meaning than what is intended in this paper, where we shall confine our attention to the alum of commerce. This article consists of a double sulphate of aluminium and potassium, or aluminium and ammonium, combined with 12 atoms of water; and is represented by the formula $KAl,2SO_4,12H_2O$, or $NH_4Al,2SO_4,12H_2O$.

It is used in the arts for a variety of purposes, perhaps the most important of which are in dyeing and calico printing. It acts there as a mordant, and will be found frequently mentioned in the earlier papers of this series, which treat of those two subjects. It has, however, a variety of other uses. The tallow-chandler employs it to harden his tallow when it is too soft. It is used in leather-dressing; and the doctors often prescribe it, on account of its astringent properties. The baker puts it into bread, to prevent the conversion of the starch into dextrine, making the bread dry and white, but at the same time rendering it less nutritious and digestible.

The alum-works in this country are not very numerous, as they can only be carried on successfully upon the very spot where the principal ingredients are found. By far the most important are in the neighbourhood of Whitby and of Glasgow, in both which places good alum-shales occur. It takes at Whitby about 130 tons of shale to produce one ton of alum; so that even the smallest charge for cartage of the rough material would be ruinous to the manufacturer.

The Whitby shales occur in the Lias formation, and are of two varieties. The one contains about 4 per cent. of sulphide of iron, 5 per cent. of carbon, and 19 per cent. of alumina; the other about the same quantity of the latter, with 8 per cent. of each of the other ingredients named. The rest is principally silica: of lime, which is very prejudicial to the alum-maker, there is only 1 to 2 per cent.

The Campsie shales, near Glasgow, belong to the Carboniferous series of rocks, and vary much more in their composition. What is known as the "top rock" contains about 40 per cent. of sulphide of iron, 11 to 12 per cent. of alumina, and 29 per cent. of carbon; the "bottom rock" about 10 per cent., 19 per cent., and 8 per cent. respectively. They do not contain more lime than those of Whitby. These two shales are used together, as the "top rock" contains an excess of sulphur, and the "bottom rock" an excess of alumina; if used separately there would be a very great waste of materials.

The first step in the manufacture is the roasting of the shale. For this purpose a very large open space is required, as immense quantities of material have to be operated upon. The Scotch shales contain so much carbonaceous matter that they might be calcined without the addition of any fuel—pyrites, when exposed to the air and occasionally wetted, having a great tendency to spontaneous combustion—the decomposition of sulphide of iron being attended with much evolution of heat. The heaps are commenced, however, by making a row of little fires, and covering them with some loose stones or bricks in order to form air-passages; upon the fires are heaped up lumps of shale, and as these begin to burn, more is thrown on until the heap forms a long continuous ridge, which, when mantled, is about 150 feet long, 20 broad at the base, and 15 high. The mantling consists of a layer of old material that has already been exhausted, which is put all over it to moderate the combustion, as without this the sulphur would be liable to be volatilised and lost. It also serves to protect the heap from the changeableness of the climate, winds, and rain. During the prevalence of high winds, it is often necessary to increase the covering, in order to prevent too brisk a combustion, which sometimes even causes the sulphide of iron to mix with the earthy substances, and run into a kind of slag, when a loss of produce is the result. The calcination of the shale requires three to twelve months' time, according to the weather, including the cooling down again after the roasting is over; this is effected by increasing the mantling, so as to exclude the air altogether.

At Whitby the heaps are made of a different form. They are there piled to 80 or 100 feet in height. In order to prevent so large a bulk of shale from becoming too hot in the centre, it is mixed with some of the exhausted mine, and carefully watched, that the mantling may be increased whenever necessary.

In wet weather little channels are made round the heaps to carry off the water which may have drained from them, as it generally contains some quantity of sulphate of aluminium which it has dissolved out. To keep up a continuous supply of roasted ore, the material is not all put into one heap, but is divided amongst several, which are commenced in succession, so that some are in different stages of advancement while what is finished is being put through the next process.

During the roasting the sulphide of iron has been decomposed, and the sulphuric acid liberated has entered into combination with the alumina, forming a soluble sulphate which has now to be removed from the earthy ingredients of the calcined shale. This is accomplished by lixiviation with water.

In the immediate neighbourhood of the calcining ground are shallow cisterns of lead or stone, into which the roasted shale is put, and spread out evenly to a depth of eighteen inches. Water is then let in through a series of taps until the shale is quite covered, and is allowed to remain for twelve hours; it is then drawn off into the clarifying cistern, where it is left to settle before passing to the evaporating pans. A fresh supply of water is let in upon the burnt shale as before, which, in its turn, passes into the clarifying cistern and the evaporating pans; a third is then introduced, but by this time the shale is nearly exhausted of its soluble ingredients, and the liquor drawn from this washing is usually too weak to be evaporated down with profit, so it is reserved to wash some fresh material. A number of these lixiviating cisterns, or "steeps," are generally ranged together, so that the weak liquor from one can be made to serve for the first washing in another steep. In the mean-time the exhausted shale is removed, and a fresh supply is introduced from the calcining heap.

The lye which comes from these washings, after having deposited in the clarifying cistern the earthy particles carried off with the liquid, contains, along with the sulphate of aluminium, a good deal of sulphate of iron, or green vitriol; and also, at Whitby, sulphate of magnesium, or Epsom salts. As both of these articles are of commercial value, the making of copperas, or green vitriol, and of Epsom salts, forms a part of the business of the alum manufacturer. If it is found that there is more sulphate of iron than aluminium, which is not unfrequently the case, it is usual to remove the first; this can be done by crystallising it out, either by simple evaporation, or by adding at the same time some old iron. If less in quantity, the whole is boiled together, with the view of throwing down the alum first. The main object of this process is to get rid of the large excess of water, and thus concentrate the solution. The plan most economical of fuel is found to be that of having very long flat troughs, with a furnace at one end and a tall chimney at the other, the flue passing over the trough, so that the flames from the surface sweep over the surface of the lye in the troughs, raising the temperature of the liquid very rapidly, and carrying away up the chimney all the vapour of water as fast as it is given off from the surface. Troughs built upon this principle, and covered with a roof to prevent loss of heat by radiation, 60 feet in length, 6 wide, and 4 deep, are capable of evaporating nearly 5,000 gallons in 24 hours. In those works where Epsom salts are also made this plan of evaporating cannot be adopted, for in that case the sulphate of magnesium would be liable to crystallise out, and form a crust on the surface of the lye, thus impeding the further progress of the evaporation. There the flue from the surface is made to pass under the evaporating pans, and the heat is communicated through the metal bottom. This plan is not so economical of fuel as the other; and the metal at the bottom of the pans is very liable to suffer, much in the same way as boilers do, from the precipitation of some sediment. It is found best to use pans lined with lead.

The boiling of the lye is carried on until all the superfluous water is driven off, and there is only sufficient left to retain the sulphate of aluminium in solution, even when it has completely cooled down. If it were carried beyond that point, the salt would begin to crystallise out, which would necessitate its being dissolved again preparatory to the next step of the process.

The concentrated liquor is run from the evaporating cisterns into large tanks, where it is allowed to become quite cold. Here it is that the potassic or ammoniacal salt is added, and, by combining with the sulphate of aluminium dissolved in the liquor, forms the double sulphate, alum, which, being only slightly soluble in cold water, is thrown down in crystals. To make potash alum, either the neutral sulphate or the chloride of potassium can be used; the latter article, familiarly known as "soap-boilers' waste," can readily be had in large quantities from the soap-works. In making ammonia alum, the refuse liquor from gas-works is used, which is converted into the sulphate of ammonium by treating it with sulphuric acid.

Having ascertained by testing the exact per-centage of sulphate of aluminium in the tanks, it is a matter of simple calculation to arrive at the quantity of either of these salts which will combine with it to make the double salt. This is dissolved in the smallest possible quantity of hot water added gradually to the liquor in the tanks, and the two mixed up together by vigorous stirring. As soon as they have properly combined, the alum is deposited in small crystals all round the walls and bottom of the tank, which is shovelled up and thrown out by the workman. After the mother liquor has drained off, the crystals are washed with as small a quantity of cold water as possible, to remove any adhering impurities. Some alum is necessarily dissolved off at the same time, but that can be again recovered, so that it is not wasted.

Both the purity and size of the crystals of alum can still be considerably improved, and therefore the process does not end here. This "first alum," as it is called, is boiled up with steam in a large stone cistern, water when boiling being able to dissolve about twenty times as much alum as when cold; it is then closed up, and left for about twelve hours to settle. The impurities which may have escaped the last operation having by that time found their way to the bottom of the boiler, the alum solution is drawn off into cooling tanks, where, as it cools, the alum crystallises out. A very perceptible improvement both in the whiteness and the size of the crystals will be seen at this stage, but it again passes through a somewhat similar process, which brings it up to the desired standard. The crystals are laid upon perforated shelves in a steam-chest, and again dissolved; as this proceeds the hot alum-liquor runs down to the bottom, and is drawn off through a pipe into the rocking-casks, where it is left to cool. The crystals soon cover all the sides, and gradually extend inwards towards the centre of the casks. These are then unhooped, and the staves removed, the mass of alum being left standing thus for several days to ensure that the crystallisation in the interior is complete. Some holes are then made in the side of the mass, by which to draw off the mother liquor remaining, and the alum is then ready to be sawn into blocks and sent to market. On the inner side the alum is then seen to be very beautifully crystallised, in large octahedral crystals.

In the foregoing description we have considered the ordinary processes of preparing alum; but the iron, which performs an important function in the first stage, is never entirely got rid of in the subsequent operations, the result being that alum contains about 0·12 per cent. of iron in the condition of ferric sulphate. Even this trace is objectionable in dyeing. An alum absolutely free from this impurity is prepared to some extent from cryolite, a mineral principally imported from Greenland, which is a double fluoride of aluminium and sodium ($Al_2F_3 + 3NaF$). The cryolite is heated with three times its weight of strong sulphuric acid, which reduces it to an anhydrous sulphate of alumina and acid sulphate of sodium, the hydrofluoric acid being given off; the sodium salt is washed out, and the sulphate of aluminium digested with warm water, to which sulphate of potassium is then added. The reaction is then the same as already described, and the pure alum crystallises out.

Some very good alums are made in the volcanic districts on the Continent, where earths rich in the most important ingredients are found, small crystals of native alum even occurring in some places. Some of the Italian alums are highly prized, on account of their purity.

In some countries alum is made with sodium, instead of potassium or ammonium; but it is not so convenient for the manufacturer, on account of being much more soluble in cold water.

The chemical constituents of alum are very widely spread in Nature; and at a price it could be produced in a great variety of ways, and from very different materials. It is not unlikely that some of these may one day be rendered more generally available. Felspar (a very common ingredient of igneous rocks) is a double silicate of aluminium and potassium, and albite of aluminium and sodium; both these can be converted into alum by replacing the silicic with sulphuric acid. Clay is a silicate of aluminium, and this also can be made available for the purpose, by treating it with sulphuric acid, and the addition of one of the alkalis.

WEAPONS OF WAR.—XI.

BY AN OFFICER OF THE ROYAL ARTILLERY.

RIFLED GUNS.

THE superiority of rifled guns in point of range and accuracy has been recognised by artillerists for more than two centuries back, and various have been the attempts during that period to construct pieces able to shoot elongated projectiles rotating on their longer axis; but these attempts one and all failed, in consequence of the backward state of mechanical and metallurgical science. It was not, however, till the general introduction of rifled small-arms during the Crimean War that rifled guns became actually necessary, in order that artillery might remain, as before, the principal arm on the field of battle.

"Such being the state of the case, it was indeed fortunate for the ascendancy of artillery that, owing doubtless to the spread of railways, suspension bridges, etc. etc., the requisite improvement in metallurgy and in mechanical appliances should have opportunely taken place in recent years. It is only lately that the manufacture of cast steel as a material for rifled ordnance has made rapid progress, whilst the difficulties which used to attend the forging of wrought iron in large masses were so great that a heavy anchor was one of the greatest achievements of the forge-master until the comparatively recent introduction of steam-hammers enabled him to forge our modern monster guns; and, thanks to the able mechanicians of the day, we have now rifling machines so perfect and easily manipulated that the operator could, if he pleased, engrave his name in the bore of a gun, and, withal, so accurate is their action that they work true to less than $\frac{1}{1000}$th of an inch, a dimension which can now be very easily measured by means of a Whitworth's micrometer, but which is fifty times too minute to be ascertained by the primitive measuring instruments of the last generation of mechanics."*

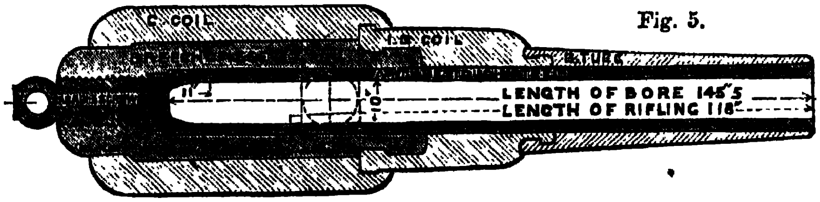


Fig. 5.

Our limited space prevents us going further into the reasons why a rifled gun should be made of stronger material and construction than a smooth-bore, beyond stating that the rifled gun is required to give a spiral motion to an elongated projectile about 2½ times heavier than the *ball* which is simply projected from the smooth-bore gun of the same calibre (diameter of bore); so that there is a good deal more strain on the former description of gun than on the latter. We must say, however, that this increased strain could not, as a general rule, be met by merely increasing the weight of the piece, for it is a well-known fact that the strength of a cylinder is not in proportion to its thickness, and that in the case of a ponderous gun of a too weak material, the interior would be ruptured before the exterior portions could come into play.

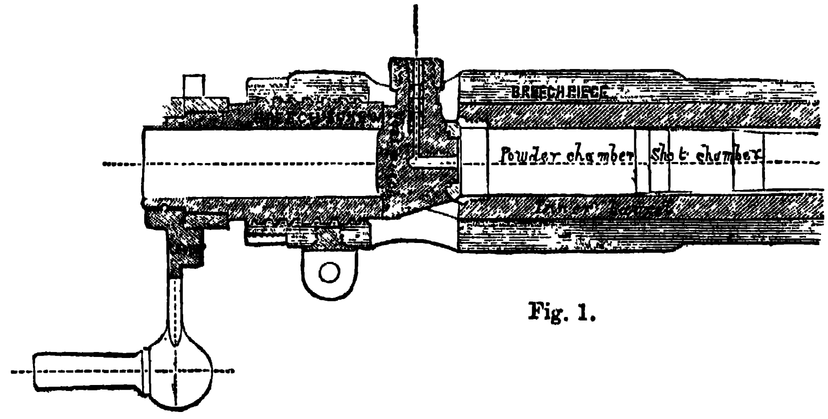


Fig. 1.

Mr. (now Sir W.) Armstrong was the first in this country who brought a system of rifled ordnance to practical perfection. The principles of his gun-construction consist essentially—

"First, in arranging the fibre of the iron in the several parts so as best to resist the strain to which they are respectively exposed; thus the walls or sides of the gun are composed of coils with the fibre running round the gun, so as to enable the gun to bear the transverse strain of the discharge without bursting, whilst the breech end is fortified against the longitudinal strain, or tendency to blow the breech out, by a solid forged breech-piece with the fibre running along the gun. Secondly, in shrinking on the successive parts together with tensions so regulated that each part shall do its due proportion of work on the discharge of the piece; thus the outer coils contribute their fair share to the strength of the gun, whereas in an ordinary homogeneous gun the inner portions receive the brunt of the explosion, whilst the exterior ones are hardly affected by it at all.

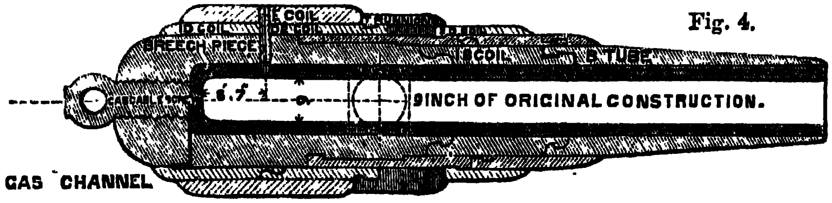


Fig. 4.

"By a combination of these two principles (which are applicable alike to breech-loaders and muzzle-loaders) a gun is obtained which may be calculated to be twice as strong as a gun of the same weight and shape made out of a solid forging."

The first gun Sir William Armstrong brought to the notice of the War Office was a breech-loading 3-pounder, with poly-grooved rifling, and lead-coated projectiles—in fact, a type of what is commonly called the Armstrong gun. It was tried in 1855, at the School of Gunnery, Shoeburyness, in Essex, and made remarkably good practice at long ranges. Heavier guns of the same description were subsequently tried; and having proved their claims to accuracy, strength, and range-power, the excellence of the system was acknowledged, and the whole series of Armstrong breech-loaders, from the 6-pounder, of 3 cwt., to the 7-inch* (100-pounder) of 82 cwt., including the 9-pounder and 12-pounder field-guns, the 20-pounder guns of position, and the 40-pounder siege-guns, was issued for land service, and similar guns were also distributed through the different classes of vessels in the navy.

All these breech-loaders are made altogether of wrought iron, each gun consisting of a coiled inner barrel, a forged trunnion-ring, and one or more coils, according to its size; for example, the 6-pounder has only one coil, whilst the 7-inch has six.

The gun is loaded through a hollow screw, called the "breech-screw;" the "vent-piece" (so called because the vent goes through it) is then dropped into the "slot," and the breech-screw being screwed up by means of the "lever," the breech is closed, and escape of gas completely prevented by means of copper rings on the face of the vent-piece and end of the barrel. The annexed illustration (Fig. 1) of a portion of the 6-pounder will explain the breech arrangement better than a page of description. The rifling is "polygroove" (we are not responsible for the etymology of this word); and the "grooves" and "lands" are nearly of the same dimensions in all the natures, the only difference being in the number; thus the 6-pounder has 32 grooves (see Fig. 2), whilst the 7-inch has 76.

The Armstrong breech-loading guns were used in active service in China, New Zealand, and Japan, and answered remarkably well. Why, then, are muzzle-loaders more in favour? Because it has been proved by experiment that they are equal to the breech-loaders in range, rapidity, and precision of fire, and much superior to them in the simplicity of their fittings and ammunition, as well as in their non-liability to wear. There are, no doubt, advantages on the breech-loading side, and we think the Prussian field-gun, with the Krupp expanding wedge and the Broadwell copper gas-check, a simple and efficient breech-loader, but we do not think that any system of breech-loading has yet been found sufficiently safe, handy, and durable for heavy guns.

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* This and the succeeding paragraphs in inverted commas are extracted from papers on the subject published in the Royal Artillery Institution Proceedings, by Captain Stoney, R.A., Assistant-Superintendent Royal Gun Factories.

* Below 7-inch calibre a rifled gun is designated by the weight of the shot and its own weight; 7-inch guns and upwards are designated by the calibre; and the weight is expressed in cwts., unless it is 5 tons or upwards, in which case it is expressed in tons.

In short, a breech-loading arrangement on a small scale, as in revolvers, infantry rifles, etc., is exceedingly convenient and satisfactory, but the difficulty of obtaining perfection of mechanism and ease of manipulation increases with the size of the weapon; and hence it is that when the introduction of armour-plated ships necessitated ordnance of great penetrative power, the British artillery authorities, after long and exhaustive experiments, adopted muzzle-loaders, and this leads us to our muzzle-loading rifled guns.

The largest gun in the English service is the muzzle-loading rifled gun of 35 tons, or 700-pounder, and the smallest muzzle-loading rifled gun is the steel 7-pounder mountain-gun, which was used in Abyssinia, and weighs only 150 pounds, that is, considerably less than a quarter of the weight of the projectile for the 35-ton gun. Indeed, it is absurd to see one of the big guns side by side with one of the little guns, and it is no wonder to learn that they are respectively spoken of as "Dignity" and "Impudence."

No other nation has got such powerful guns as we have. Herr Krupp, of Essen, the great German steel gun manufacturer, exhibited in Paris, in 1867, a breech-loader weighing 50 tons, and intended for a 1,000-pounder, but we believe it has never been fired. Russia and one or two other Continental powers have provided themselves with Krupp's steel breech-loaders, from 300-pounders downwards; while the remainder have followed our example, and adopted the heavy Armstrong muzzle-loaders for their ships and forts.

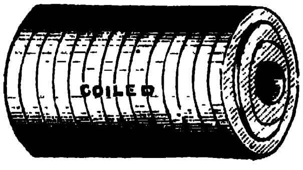

Fig. 6.

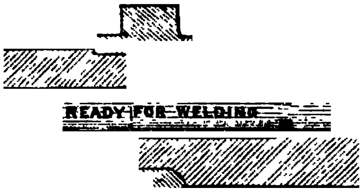

Fig. 8.

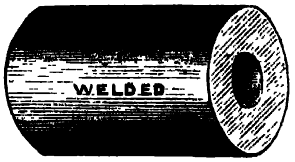

Fig. 7.

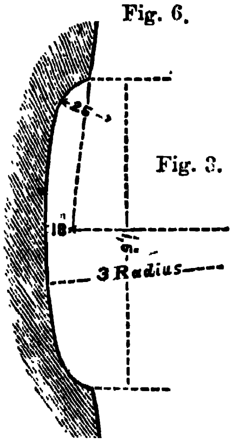

Fig. 3.

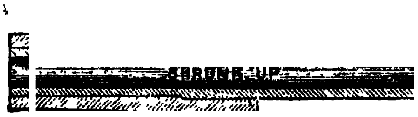

Fig. 10.

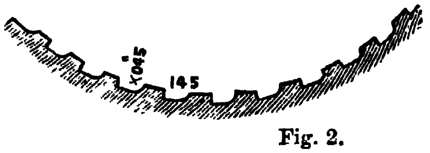

Fig. 2.

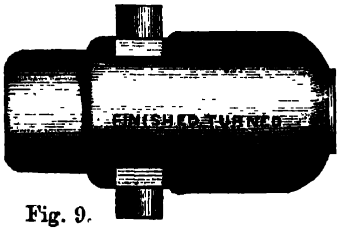

Fig. 9.

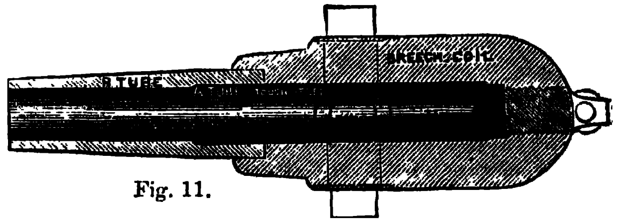

Fig. 11.

The 7-pounder mountain-gun is made out of one block of cast steel, bored out and tempered in oil; that is, the block of steel, after being roughly bored out for the barrel, is put into a furnace, where it is raised to a high heat, and then plunged into an adjacent bath of rape oil, in which it is allowed to cool and to soak for twenty-four hours. This process not only strengthens, hardens, and toughens the steel, but also increases its elasticity; and for a small gun the material so treated may be considered quite safe, and not likely to burst explosively. But a gun altogether of steel, even though thus improved, is of too snappish a nature to be trusted to bear the great and sudden shock of large discharges of powder, and so we deem it prudent to coil the steel round and round with wrought iron, after Sir William Armstrong's fashion; all our muzzle-loading guns,* therefore, from the new 9-pounder field-gun, of 8 cwt., to the 700-pounder, of 35 tons, are lined with steel (which, from its statical strength and hardness, is the best material we know of for withstanding the strain and friction on a rifled barrel), and have on the exterior coiled wrought iron, which, from its pliant and fibrous character, is capable of checking and counteracting any explosive tendency on the part of the steel.

Up to 1867 all our heavy muzzle-loading guns were built up with many coils, like the breech-loaders, and fired (as they do still) projectiles having two studs for each groove, the number of grooves increasing with the size of the gun—the 7-inch having three grooves, the 9-inch six, and so on. Fig. 3 shows a full-size section of the muzzle-loading groove.

"The 'Woolwich' guns built on this system, and lined with toughened steel, are sound and strong; but from the fine iron used, and the great number of exquisitely finished coils and a forged breech-piece, their manufacture was very costly; and as it was probable that several heavy guns would be required, the War Office pointed out the desirability of procuring some cheaper plan. Accordingly, the attention of the Royal Gun Factories was devoted to the question, and their efforts have been crowned with success. First, a cheaper iron, sufficiently strong for the exterior of the gun, was obtained; and, secondly, the plan which was proposed by Mr. Fraser, the principal executive officer of the department, was found to be less expensive than the original one.

"Mr. Fraser's plan is an important modification of Sir W. Armstrong's, from which it differs principally by building up a gun with a few long double or triple coils, instead of several short single ones and a forged breech-piece. There is less material, less labour, and less fine working, and consequently less expense required for the 'Fraser' or present service construction."

For example, in addition to the steel barrel and cascabel screw (breech-plug), a 9-inch gun of the Armstrong or original construction consists of a forged breech-piece, a B-tube, a trunnion-ring, and seven coils—ten distinct parts—shrunk on separately (Fig. 4); whereas a "Fraser" gun has only two, three, or four parts to be shrunk on, according to the size of the gun—the 7-inch and 8-inch having only two extra parts, the 9-inch three, and the 10-inch and higher natures four (Fig. 5).

From the fewer parts and the cheaper iron employed, the Woolwich guns of the present construction only cost about £70 a ton, whereas those built on the original plan cost £100 a ton.*

Without entering into the theory of construction, it must be sufficient to state that specimen guns of this cheap construction were tested to destruction, and were proved beyond all doubt to be as sound and durable as their original prototypes; and we have no hesitation in asserting that England now possesses the simplest, safest, and cheapest system of heavy ordnance in existence.

To give an idea of the way in which our heavy guns are built up, we will take as the simplest example a 7-inch gun of 7 tons.

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* We have also 9-pounder field-guns altogether of bronze for service in India, and some 64-pounders converted from 32-pounder cast-iron smooth-bores, but these may be said to be exceptional pieces.

* A steel gun of Krupp's or Whitworth's plan costs about £170 a ton.

The gun consists of only four separate parts—namely, the A-tube, or inner barrel of steel, the cascabel, the B-tube, and the breech-coil.

The steel tube is bored out of solid ingot to within a few inches of the end; it is then toughened in oil, like the 7-pounder mountain-gun already described.

The cascabel is a forged block of wrought iron, with a screw-thread cut on it.

The B-tube is formed by two coils joined together, each coil being made of one long bar of wrought iron, brought to a high heat, wound spirally round an iron mandrel, and then longitudinally welded under a steam-hammer.

The breech-coil is somewhat more complicated; it consists of a triple coil, a trunnion-ring, and a front double coil, all welded together. The triple coil is made by winding three red-hot bars of wrought iron successively over one another, and then, having raised the mass to a white heat, welding it like the single coil, for the purpose of closing its folds (Figs. 6 and 7).

The front coil is made of two bars, in a similar manner. The trunnion-ring cannot be coiled, owing to the projection of the trunnions; it has, therefore, to be bored and formed out of a solid forging of wrought iron.

In order to join the three parts of the breech-coil into one solid mass, the trunnion-ring is expanded by heat, and dropped on a shoulder cut for it on the triple coil; the front coil is next dropped into the upper portion of the trunnion-ring, which is allowed to cool and contract, and thus bind the two coils together (Fig. 8). The mass is then heated and welded, and finally bored and turned to the proper size and shape (Fig. 9).

The parts of the gun being all ready, they are put together in this way:—The steel tube (having been finely turned) is placed upright in a pit, and the B-tube, which is just too small to go over it when cold, is heated and expanded, and is then dropped down on the chase end of the steel tube, which it grips in shrinking as it becomes cold (Fig. 10). The mass thus formed is inverted, and the breech-coil being heated, is shrunk on in a similar manner. Finally, the cascabel is screwed carefully in, and thus the gun is completely built up (Fig. 11).

Some of our early rifled guns were manufactured by Sir William Armstrong and Co., at Elswick, Newcastle-on-Tyne, where some cast-iron smooth-bore guns are still "converted" for the Government, on Major Palliser's principle—that is, an old smooth-bore, a 32-pounder, for example, is bored out and lined with a wrought-iron barrel, and converted into a rifled 64-pounder; but all our new guns, big and little, are now made in the Royal Gun Factories at Woolwich, where 6,000 tons' weight of guns of all calibres can be manufactured in one year. It may, however, fix our ideas better to give the actual guns which are to be made during the current year (1871). They are as follow:—

12-inch guns,	of 35 tons	(700 pounders)	. . .	13
11 ,,	25 ,,	(530 ,,)	. . .	19
10 ,,	18 ,,	(400 ,,)	. . .	83
9 ,,	12 ,,	(250 ,,)	. . .	46
7 ,,	7 ,,	(115 ,,)	. . .	28
7 ,,	6½ ,,	(115 ,,)	. . .	30
64 pounders,	of 64 cwt.		. . . .	35
40 ,,	35 ,,		. . . .	20
16 ,,	12 ,,		. . . .	160

All the above are wrought-iron muzzle-loading rifled guns, lined with steel. There are, in addition—

Bronze 7-pounder mountain rifled guns, of 3 cwt. .	15
32-pounders, of 58 cwt., converted to 64-pounders .	100

One projectile for the 35-ton gun (700-pounder) exceeds the weight of all those thrown from the whole broadside of a 74-gun ship in Lord Nelson's time. So much has the power of our guns increased since our last great naval battles!

PRACTICAL APPLICATION OF THE FINE ARTS.—III.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

THE MANUFACTURE OF COLOURED GLASS.

The manufacture of glass for coloured windows has improved very much of late years, yet it is confessed by one of the most successful of modern manufacturers that he has "never hitherto been lucky enough to find a single piece of modern glass equal for lustre and strength of character to the old manufacture." It is well that this spirit of humility should possess our manufacturers, and should urge them on to continued exertions after still more perfect glass. Yet they have acquired a considerable knowledge and dexterity in their work, and in many respects the results are as good as can be hoped for.

A great impulse was given some years back to those who supplied the glass-painters with the materials on which they were to work, by the researches and experiments of the late Mr. C. Winston. He not only procured careful chemical analyses of different kinds of twelfth-century glass, but he searched through the various records that have been left by old writers of the processes of manufacture. Further than this, he endeavoured to procure the materials from the very spots frequented by the workmen of old, and he employed Messrs. Powell of Whitefriars to try various experiments for him in the manufacture of different kinds of coloured glass. Some of these experiments were highly successful, and those manufacturers, together with Messrs. Hartley of Sunderland, and W. E. Chance of Birmingham, have profited greatly by the experiments of this amateur, and they, especially the latter, have since followed up the line of inquiry here indicated, and arrived at results sufficiently satisfactory, which, however, must be qualified with the reservation given above.

The process of manufacture is much the same as that adopted for the various other kinds of glass, such as that used for transparent windows and for glass vessels; the kilns and working pots are the same, and perhaps in this may arise some of the defects of the modern glass, for in the greater part of the glass required now-a-days, the chief object is perfect transparency and homogeneity; whereas in coloured glass, one of the principal beauties is the irregularity arising from air-bubbles and other imperfections. The early manufacturers made use of open pots; now the receptacles for the molten glass are entirely covered in, having holes at the side, through which the material can be extracted. The object of the covering is to keep out all kinds of impurities that might be carried into the pots by the furnace, especially gases which would favour the decomposition of the materials of which the glass is composed. Now, no doubt these occasional interferences with the manufacture caused the production of all kinds of irregularities, for Theophilus especially mentions that certain colours are to be obtained by the chance results of lengthy melting: we may conclude, therefore, that the open pots facilitated the production of great varieties, some portions of which would probably turn out valuable.

In another respect this manufacture differs from that of clear transparent glass. It was said before that the air-bubbles formed an additional beauty in coloured glass. Paradoxical as this may seem, it is really so, and the cause of the anomaly is this, that the air-bubbles "hold" the light; each little globe of air catches the beams as they attempt to pass through it, and refracts them with each change of medium, and in consequence the light which would pass obliquely through the pane is diverted in various tracks out of the direct line of the sunshine. This causes an appearance of glimmer frequently noticeable in ancient glass, and absent in much of modern, observably so in German, glass. In order to produce these air-bubbles, the glass has to be used before it is thoroughly cooked, that is, it is not melted so fully or so long as if it were intended to make it homogeneous and transparent. The effect of these air-bubbles may be seen on holding two pieces of similarly coloured glass in different positions in the direct rays of either sun or artificial light. Pieces of glass that seem to possess similar colour and brightness when seen against a plain sky, have very different effects when catching some of the slanting rays, according to the amount of irregularity in the texture of the glass. A variety, too, in the thickness of the pane adds a charm which is very pleasing to the eye, which would become very wearied by looking at a flat surface evenly coloured.

The composition of the glass is the same as that of a common glass of rather a soft character, the main portion of the materials being the same in all cases. This groundwork is usually formed of silica, carbonate of soda, carbonate of potash, carbonate of lime, lime, with a trace each of alumina, common salt, and sulphate of soda. To this common mass is added the various colouring matters. These are taken up and dissolved in the liquid glass without being chemically combined with it.

Coloured glass, therefore, is a kind of solution in glass of a metallic oxide not in sufficient quantity to make the glass opaque, but enough to give various degrees of colour. Blue is produced by the addition of oxide of cobalt in various quantities and in various degrees of purity. The impure oxide, just as it is procured from the mines in Germany, appears to produce the pleasantest tint. Oxide of iron is sometimes added, as well as that of manganese—materials which, in ordinary glass, have the property of nearly neutralising one another. A little oxide of copper, tin, and lead added to this, deadens the colour, and makes it deeper. It is in the blue glass, however, that the difference of the old glass from the modern is most observable. Probably, if the native oxide of cobalt, with all the impurities that naturally cling to it, were more frequently used instead of the imitation of the natural impurities made by the addition of other materials to the refined oxide, the old colour could be reproduced more exactly; for the ancients, who knew nothing of exact chemical methods, were apt to make use of those materials which came ready to hand, and which produced the results they required.

Protoxide of copper (Cu_2O) in very minute quantities, combined with the iron and manganese as before, produces a bright yellow glass. If used in larger proportions, and sometimes with protoxide of iron, it furnishes the deep ruby-red, which is such a striking and beautiful colour. The secret of the manufacture of this tint, which is one of the most successful, was for a long time lost, but was recovered about the year 1830, in France. A larger proportion of iron changes this red into a reddish-brown. Impure manganese, containing a considerable amount of iron, results in a kind of madder-brown; whilst a much paler glass of something of the same colour is produced by a smaller quantity of manganese with red lead instead of copper.

Various shades of green are produced by combinations of a great variety of materials, such as arsenic, nitrate and bichromate of potash, with the oxide of iron and copper mentioned above. These are the principal colours used at present. Slight variations of quantity in any of the materials change the tint, whilst differences of thickness in the glass itself, or in the proportion of the metal or common material of the glass, alter the tone and depth of colour.

When the materials have been sufficiently melted, and, as we said previously, before they have arrived at a perfectly homogeneous condition, the glass-blower takes a quantity of the metal, weighing some pounds, upon the end of what is technically called his *iron*. This iron is a rod or tube of some four or five feet in length, with a bore of about one-eighth of an inch. The lump of metal is blown into an oval bubble of some two feet in length, and when this is completed, the end farthest from the iron is opened by means of a *punt* (a solid iron rod, lighter and smaller than the *iron*), so that the glass assumes the form of a rough cylinder, which is now detached, by means of a cold iron, from the iron. The cylinder thus made is split down its length in the same manner as it was detached from the iron, and it is thus put on one side to cool. The next process is that of annealing, and this is accomplished by means of an air-oven, a low arched furnace fitted with iron trays filled with chalk or lime. On this lime the partially opened cylinders are placed, and when exposed to the heat, they gradually extend themselves until they lie flat upon the level bed of chalk. The metal, after the lapse of a few hours, is ready for use.

When it has arrived at this stage, the glass is usually of considerable thickness, frequently as much as a quarter of an inch, which is also the measurement of much twelfth-century glass; but the commoner sorts, manufactured in the earlier portion of the present century, were scarcely more than a sixth of this size.

Much of the ruby glass, and many of the brighter tints that partake of red, consist of what is called *flashed* glass. This variety is blown as follows:—The workman first dips his iron into a pot containing colourless, yellow, brown, or other metal, and when he has accumulated a sufficient quantity, he just dips the mass once entirely into the ruby metal, thus obtaining a coating of the red colour over the whole. This is then blown as before into a cylinder, which consists of a thick foundation of the principal metal with a thin coating of the ruby. This process gives a greater opportunity for modification of colour and tint, besides admitting of a variety of colour by removing the red surface, and either leaving the original glass beneath, or giving this latter a stain.

From what has been said above, it will be seen that some considerable amount of judgment is required in choosing the glass to be used in each particular portion. Those parts which have numerous air-bubbles are usually to be preferred on account of their holding the light; uneven pieces, because they are agreeable to the eye; pieces in which the colour is shaded, because it may so suit the design; thick glass, because it possesses a greater depth and richness of tone. Owing to the great impetus our manufacture acquired, partly from the researches of Mr. Winston and others, and partly on account of the increased demand for stained glass in England caused by the revival of a taste for ecclesiastical architecture, the English glass has become especially celebrated throughout the Continent, so that the Germans who have long been celebrated for the brightness of their colouring, and their manufactures in coloured glass, now come to England for the material wherewith to make their windows. Their own glass is found to be too flat, and consequently dull, though so highly coloured. If our manufacturers continue their course of steady perseverance and desire to excel, no doubt they will be able to hold their own against the world, but if they once attempt to pass off inferior glass, the evil will quickly recoil on their own heads. It is not sufficient merely to put together what appear to be the chemical ingredients of a particular glass: the source whence these ingredients come must be carefully observed, and the process of manufacture must receive the most patient attention.

MINING AND QUARRYING.—VIII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

MANUFACTURE OF PIG-IRON—EXTENT OF TRADE—BLAST-FURNACES—DESCRIPTION—SIZE—CALCINATION OF ORES.

The smelting of the ironstone, by which the metal is separated from the other ingredients with which it is combined and formed into pig-iron, is a very large trade of itself; many ironmasters, especially in Scotland, do not undertake any of the subsequent processes to which iron is subjected in order to render it fit for use in the arts. Scotch pigs, of which no less than 1,180,000 tons were made in 1863, are well known as an article of commerce, and are sent to many parts of the world, just in the state in which they came from the blast-furnaces. It is estimated that the production of pig-iron in the British Isles is just about equal to the entire amount furnished by the rest of the world. The annual yield of the blast-furnaces in the United Kingdom now exceeds 5,000,000 tons.

Pig-iron is very rough in its exterior; within it is of a granular or crystalline structure; and it is usually very brittle. It is generally classified according to four qualities—Nos. 1, 2, 3, and 4—each having its own particular merits, according to the purpose for which it may be required.

The present article will be confined exclusively to the production of pig-iron.

The smelting of iron ores requires the adoption of a furnace capable of being raised to a very high temperature; a supply of fuel, and of limestone to serve as a flux. In order to stimulate the combustion, a strong current of air is forced into the furnace at the bottom, which, passing through the charge, makes its escape by the chimney; hence it is termed a blast-furnace. The pouring in of a current of cold air tended, however, to reduce the temperature in the lowest part of the furnace, just where it was needed to be hottest. To obviate this objection, the air is heated to a very high temperature on its passage from the pumping-engine to the furnace, which, by way of distinction from the other, is called the *hot-blast* process. This was the invention of one Neilson, a Scotch engineer, who took out a patent for it in 1828. It led to a great extension of the iron trade, coupled with an important reduction in the price of iron. The cold-blast is comparatively little used at the present time, as the iron thus made is much more expensive, though for quality it is highly esteemed by some people.

The form and nature of a blast-furnace for the smelting of iron has now to be considered at some length.

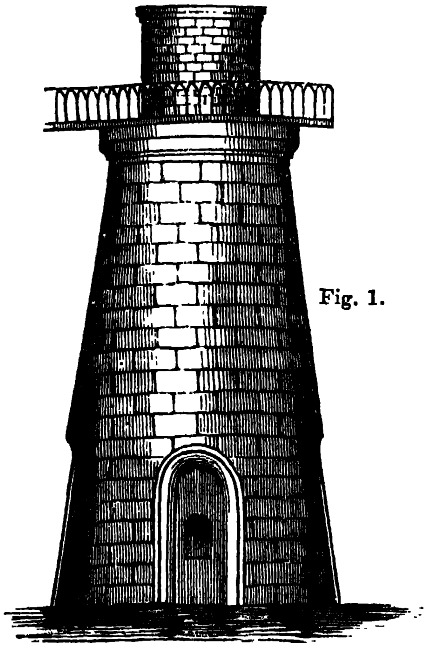

Fig. 1.

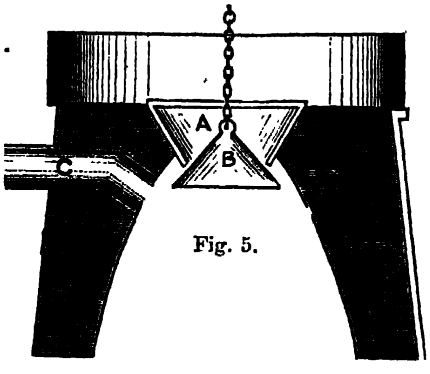

Fig. 5.

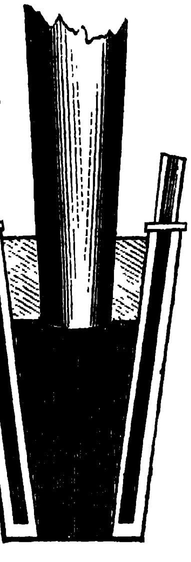

Fig. 4.

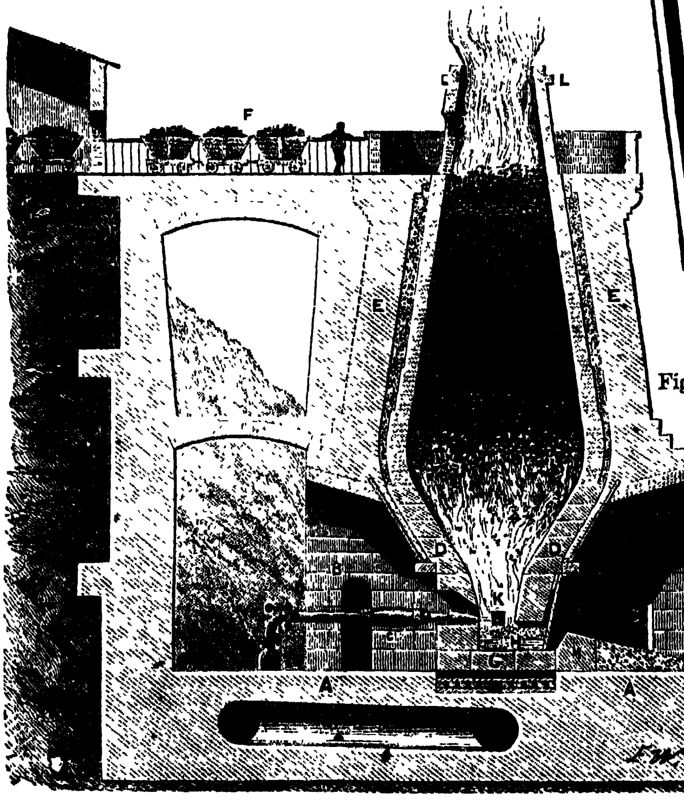

Fig. 2.

Fig. 1 represents the exterior elevation of a cupola or blast-furnace of the ordinary pattern. The former term is applied to the smaller ones, which are generally less solid in their construction, and cased with iron, though the principle upon which they are built is the same. Fig. 2 is a vertical section, and Fig. 3 a horizontal one at the level of the tuyere or twyer holes. The base, A, is generally firmly built of grit or sandstone, specially selected for its power of resisting heat. The arches, B, over the twyers, C, and the boshes of the furnace, D, are also built of the same material. The cone, E, is constructed of common bricks, but lined on the inner side with fire-bricks, a small space being left between, which is filled with sand. This arrangement is made to neutralise as far as possible the expansion due to the heat of the charge, which would otherwise be liable to loosen the brickwork. Sometimes the additional precaution is taken of binding the whole furnace exteriorly with hoops of iron, especially when it is desired to reduce the thickness of the brickwork. The charge is introduced through a door at the top of the cone, which is approached by the external gallery, F; and as the quantity of material which has to be brought up to this level is very considerable, it is generally so arranged that a tramway can be carried either on the level or by an inclined plane to this gallery, so that the charge can be tipped in from iron barrows. The angle made by the boshes, D, and also that of the cone, E, is a matter of importance, and depends to some extent both upon the character of the ironstone intended to be smelted and of the fuel to be used for the purpose; the great desideratum being that the charge shall not sink down into a mass at the bottom of the furnace till it has passed through a certain stage of the process, otherwise the action of the blast would be greatly impeded. A form more or less contracted towards the top is generally approved of (though many are, nevertheless, built with parallel sides), because the heat cannot otherwise be so well maintained in the upper part of the furnace. In the majority of more modern furnaces the boshes are carried up higher, and at a less angle than in the drawing; and some are made to curve gradually from the part where the width is greatest to the top of the hearth, G; the avoidance of any angle being for the sake of obviating the risk of any lodgment of the half-melted charge at the top of the boshes, which would occasion much trouble. The width of the hearth has latterly been considerably increased, which also necessitates, of course, a reduction in the size of the boshes. The throat, K, should be in diameter about one-half that of the extreme inner width; a narrower opening leads to an increased consumption of fuel, while at the same time reducing the make of iron. At the bottom of the hearth, G, in front of the lower orifice, H, is placed the tymp-stone, M, and plate, which is firmly fixed in its place, and the interstices filled in with clay. Between this and the dam-stone, which is immediately before it, is a small hole through which the molten slag flows out down an inclined plane, called the cinder-fall, shown at L, the hole itself being termed the cinder-notch. At the bottom of the dam-plate, and therefore communicating with the very lowest part of the hearth, is the tap-hole, which (except when the iron is being drawn off) is kept closed by ramming in sand. The tymp-plate, which thus forms the upper portion of the doorway of the hearth, is often made of iron, containing pipes inside, through which cold water is made to flow constantly to keep the plate cool. These are distinguished by the name of "water-tymps."

In front of the furnace, and opposite to the tap-hole, is a channel the use of which is to convey the iron as it runs out into the moulds, which are made of moulding sand, and are protected from the effects of the weather by being covered with a shed.

The twyers, c, convey to the furnace the draught of air necessary to promote the combustion. They vary in number from two up to a dozen or so, but three is very common, as shown in the diagram. Since the introduction of the hot-blast principle the twyers and supply-pipes are made of iron, and the nozzle is made of a hollow piece of wrought iron, as shown in Fig. 4, through which a stream of cold water is made to pass continually, in order to keep it cool.

The blast itself is produced by a steam-engine driving a piston in a cylinder which has valves opening inwards both at top and bottom, to admit the air, so that in both the ascending and descending stroke of the piston the air is forced out of the cylinder into a large receiving chamber, from which it again passes in iron pipes through the stove or oven to the twyers. The receiving chamber is made of a large size, so as to regulate the force of the blast, and render it continuous instead of spasmodic. From the receiver a pipe conducts the air through the heating oven, usually a close chamber with a furnace below and a flue above, the intermediate space being almost filled by the convoluted pipe so arranged as to present the largest possible surface to the heating power. Another short piece of pipe conveys the heated air from the oven to the twyers. The ovens are placed as near as possible to the blast-furnaces, so that the blast shall not have the opportunity of cooling in passing from one to the other. The greater the heat to which the blast is raised the better does it answer the purpose, as the requisite temperature of the furnace can then be maintained with a less expenditure of fuel. The heat of the blast should not be less than 600° Fahrenheit.

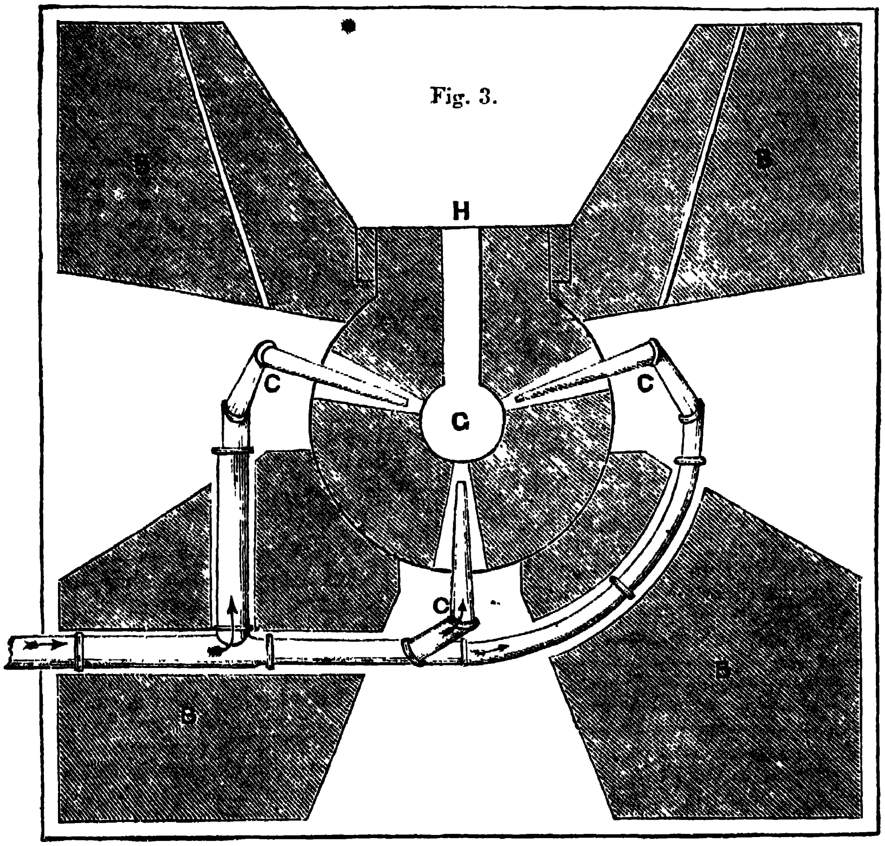
Fig. 3.

The chimney, K, extends somewhat above the charging gallery, in order to carry off the smoke and heated air which have passed through the charge; in some of the more modern iron-works, however, these heated gases are not allowed to go to waste, but are carried down again by a flue, and are made to serve instead of a furnace in heating the ovens just described. It is considered by some that the current of air through the furnace is thereby weakened, and that the temperature suffers in consequence; but it is maintained by others that this loss is more than compensated by the saving effected in the heating ovens. This requires a modification of the upper part of the furnace, and instead of having a chimney, an apparatus is substituted, called the "bell and hopper," which the accompanying drawing (Fig. 5) will serve to illustrate. Instead of charging the furnace through a door just below the chimney, the materials are thrown into the hopper, A, and then by means of a wheel and chain the bell, B, is lowered, when all the contents of the hopper fall into the furnace, and the bell is then drawn up again. The waste gases cannot escape in this direction, but are carried off by a pipe at the side, C, and are made to do duty as a source of heat.

A great deal of difference of opinion exists as to the best size of blast-furnaces, more especially as this depends very much on the character of the ore and fuel. In Scotland, for instance, though some have been built 65 feet high, the large ones are not found to work well, and a preference is given to those of about 50 feet. This is also about an ordinary size of the more modern furnaces in Wales and the midland counties. Such furnaces will have a capacity of 7,000 to 8,000 cubic feet. In the northern coal-field, however, coke of very great strength is produced, a cube of 2 inches each way being able to support (even when heated) a ton weight without being crushed; in the Cleveland district, therefore, where this very strong coke is used, the tendency has constantly been to increase the size of the furnaces, and the largest of them have proved the most economical in working. A few years ago, even in this district, 75 feet was the extreme height; but now there are blast-furnaces at work 85 feet in height from the hearth to the platform, 28 feet greatest internal width, and the diameter of the hearth 8 feet. These dimensions will give a cubic capacity of something over 30,000 feet; and each such furnace produces 490 to 500 tons of pig-iron per week, at a consumption of 20½ cwt. of coke for each ton of iron made.

It takes a considerable time and expense to bring a blast-furnace up to the heat required; and when this is done the furnace is said to be "in blast," or "blown in." It is then maintained without intermission until, for the purpose of repairs, or because of the price of pig-iron being too low, it is found necessary or desirable to put it "out of blast." Being in blast, the smelting proceeds continuously; the charge is constantly supplied from the gallery above, as the contents sink down in the furnace; and the liquid metal, having trickled down through the mass into the hearth, G, is drawn off about every twelve hours, which is called "tapping the furnace."

The charge varies considerably according to the quality and nature of the ironstone, and also to some extent upon the character of the fuel used. The ore used always to be calcined or roasted first; and though this preparatory process is not so necessary now as it was before the invention of the hot-blast, it is still very generally done. This used to be accomplished by simply making a long heap of ironstone intermixed with small coal, and then setting fire to it at the windward end. It will gradually burn all through its length, just in the same way as clay is burnt for road-making. The calcining heaps, however, occupy a very great space, so that in the larger works it is more usual now to roast the ore in kilns very similar to those used for burning lime; they are rather more economical of fuel, and in hilly districts they are generally so situated that the door of the kiln shall be on a level with the gallery of the blast-furnace, so that the roasted ore can be readily wheeled from the one to the other. The blast-furnaces are therefore erected on the low ground at the hill-side, and the calcining kilns as near as possible at the higher level, the two being connected by a light iron gallery. The calcining operation in kilns is a continuous one, the raw ore being put in at the top and the kiln kept full, while the roasted ore is withdrawn through the door below. The black bands of Scotland contain sufficient carbon to burn in kilns without the addition of other fuel; they lose from 40 to 50 per cent. of their weight during this operation, the calcined ore containing nearly 70 per cent. of iron. The clay bands lose less weight, and contain about 50 per cent. of iron after roasting. The loss of weight is due to the volatilisation of the water, carbonic acid, sulphur, and other ingredients. The roasted ore should be preserved from exposure to the weather, as it is liable to absorb again a great deal of water.

TECHNICAL DRAWING.—XXXVIII.

DRAWING FOR STONEMASONS.

A CONCISE HISTORY OF MASONRY (*continued*).

It was, however, different with the Roman masons; although, it is true, many of their temples were Greek in character, and most of them rivalled those of that nation in size and in the vastness of the material employed; the blocks of stone, for instance, in the architrave of the Temple of the Sun measure 16 feet 6 inches long, 9 feet 6 inches high, and about 6 feet thick, or nearly 50 tons in weight. But in general character there was less of that ponderous strength that characterised the Egyptian and Grecian Doric, and much more science in the construction—especially as regarded economy—whilst in point of artistic beauty the Romans were far below the Greeks.

The early Romans can scarcely be said to have possessed any style of building of their own; they for the most part borrowed their ideas from the Etruscans (who inhabited a part of Italy now known as Tuscany), and from the Greeks at a later period. In the time of Romulus their buildings would seem to have been of the most rude description, their dwelling-houses being composed principally of straw; and even at a somewhat later period their temples were only small square erections, scarcely large enough to contain the statue of their idol.

Ancus Martius was the first king who commenced works of a large class, requiring skill in their construction; and his first attempt was the building of the city and port of Ostia, at the mouth of the Tiber. Tarquin the Elder brought with him the skill and enterprise of the Etruscans, and set about improving the city with energy and perseverance. His first work was to erect the grand circus; he also constructed the walls of the city with large hewn stones, and commenced the great cloaca, or public sewer. This great work, which was considered to be one of the wonders of the world, was constructed of wrought stones, and was of such dimensions that a wagon loaded with hay could pass through it, and was carried through rocks and under hills, overcoming every engineering difficulty.

To whatever nation or race the invention of the arch may be attributed, it is clear the Romans were the first to bring it into general use, and they were the first in Europe to use the true dome in covering their temples. Besides this, they had not only good lime, but plenty of *puzzolana*,[*] and therefore their mortar and cement were of first-rate quality. To these advantages we may attribute the vast works which to the present day amaze the spectator, who cannot view the Roman cloacæ, aqueducts, amphitheatres, basilicæ, walls, towers, tombs, domes, harbours, etc., without wonder at the enterprise of the people and the skill of their masons.

As the whole subject of Gothic architecture forms a separate course of lessons, it is not intended here to enter fully into that subject, nor into the Byzantine, out of which it grew; nor the Saracenic, which was a rendering of architectural and ornamental elements under certain religious restrictions: a brief mention of the characteristic features of the period are therefore only necessary.

After the ruin of the Roman Empire, and the irruption of the savage hordes over the whole of civilised Europe, the art of masonry, like all others, declined to the lowest ebb. Had it not been, in fact, for the erection of rude forts and towers, it would have become extinct. In England we owe its revival to the Normans who came over with William I. in 1066; and next, no doubt, to the Crusaders, who had witnessed with admiration the marvellous lightness of the buildings in the East, and who brought back with them the arts and learning of the Arabians, especially their mathematical science. From these sources pointed architecture, no doubt, took its rise; and massive cylindrical pillars, composed of many small pieces of stone, small circular-headed windows, walls of vast thickness, with very shallow buttresses and plain groining without ribs, became changed to light-shafted piers and delicately-moulded arches, windows rich with varied tracery, panelled walls, with bold buttresses, surmounted by niches and crowned by pinnacles, and groined roofs fretted with a network of ribs, and studded with richly-carved bosses at the points where they crossed each other, were gradually introduced until the whole system of what has been termed the "Gothic" style was perfected.

In the sixteenth century a revival of classic architecture took place. The Gothic style had become much debased, and Roman or Italian styles were introduced into this country by Inigo Jones,[*] who was born in the year 1572, and whose distinguished works at Greenwich, Whitehall, and Covent Garden will ever secure him a place among names of the highest reputation.

Sir Christopher Wren,[†] an eminent mathematician, philosopher, and architect, executed very many of the finest buildings in London and other parts of England in the modern style. St. Paul's Cathedral in London, inferior to none but St. Peter's in Rome in point of magnitude, is justly considered one of the finest works of modern times. The exterior cupola of St. Paul's is constructed of oak, and is sustained by a cone of eighteen-inch brickwork, which has a course of stone the whole thickness—every five feet. Sir Christopher Wren formed an excellent school of masonry; the works at St. Paul's and other public buildings carried out under his superintendence being executed in a very superior manner. Besides this, with the assistance of

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[*] Puzzolana is a substance formed of volcanic ashes more or less compacted. It derives its name from Pozzuolo, as also Pulvis Puteolanus, from Puteoli, situate near Mount Vesuvius, from which these ashes are ejected, and in the vicinity of which it abounds. It occurs in various colours—white, red, or black, reddish, or reddish-brown, grey, or greyish-black. That of Naples is generally grey; that of Civita Vecchia is more generally reddish, or reddish-brown. The red variety is the proper puzzolana; the black and the white sorts are called in Italy *lapillo* or *rapillo*. The ashes which overwhelmed Pompeii now form an immense bed of white puzzolana. The surface of this substance is rough, uneven, and of a baked appearance; it comes to us in pieces, from the size of a nut to that of an egg. When mixed with a small proportion of lime it quickly hardens, and this induration takes place even under water. The ancients were well acquainted with this substance and its properties, and among them its principal use, as it has been also in modern times, was that of mixing it with their cements for buildings sunk under the sea. As it hardens and petrifies in water, it is of particular service in making moles and other buildings in maritime places.

[*] Inigo Jones was born in the neighbourhood of St. Paul's, London, in 1572. His great aptitude for drawing attracted the attention of the Earl of Pembroke, who sent him abroad for four years to study the masterpieces of architecture in France, Germany, and Italy. In 1612 Jones re-visited Italy, further to improve his style, and on his return to England he was appointed Surveyor-General of the Royal Buildings. His masterpiece is considered to be the Banqueting House at Whitehall. He also built the church of St. Paul, in Covent Garden, Ashburnham House, Surgeons' Hall, etc. He died in 1653.

[†] Sir Christopher Wren, the renowned English mathematician and architect, was born in Wiltshire in 1632. He was educated first at Westminster School, and subsequently at Wadham College, Oxford. After the great fire in 1666, Wren drew plans for the entire rebuilding of London; few, however, of his recommendations were adopted. He was the architect of St. Paul's; and in 1710, in his seventy-ninth year, superintended the placing of the highest stone in the lantern by his son, the work having occupied thirty-five years. Besides this, he built fifty churches, the late Royal Exchange in 1667 [the present was built by Mr. (now Sir William) Tite, and opened by Her Majesty Queen Victoria in 1844]; the Custom House in 1668; Temple Bar in 1670; the Monument in 1671; the Royal Observatory, Greenwich, in 1675; Chelsea Hospital, 1690; Greenwich Hospital, 1696; Marlborough House in 1709; the upper portions of the towers at the west front of Westminster Abbey in 1713, etc. He died in his chair in 1723, aged ninety years. The following inscription marks his tomb in St. Paul's—"Dost thou seek his monument? look around."

Grinling Gibbons,* he formed an excellent school of architectural carvers. He was very particular in the choice of his stone. It is said that when the stone for St. Paul's had been quarried in the island of Portland, it was exposed to the weather on the sea-beach for three years before he permitted it to be used; and the result of his care is that amongst all his buildings there is scarcely a failure or a defective block.

The art of masonry was well upheld in the eighteenth century by Vanbrugh, Hawksmoor, Gibbs, and Lord Burlington. These were followed by Sir William Chambers, who built Somerset House; Dance, the architect of Newgate Prison; and Sir John Soane, who built the Bank of England. But shortly after cement works became so general that masonry suffered. "Besides this," says Mr. Ashpitel, "the heavy duties imposed on the transport of stone by sea, and the high prices which all material bore during the war, threatened to reduce masonry to its lowest." The revival of Gothic architecture has renewed the use of freestone, and has taught our masons the art of working tracery, groined roofs, flying buttresses, and such use of stone as was supposed, scarcely a century ago, to be one of the lost arts.

Besides this, the abolition of duties and the introduction of many facilities of transport by steam, both by land and water, has so reduced the price of stone, that in many places the use of cement is a false economy.

Further, the facility with which not only the upper classes but working men can visit other countries, has tended, whilst elevating the taste of employers, to improve the mental appreciation and manual skill of our artisans; and they have thus become qualified to execute the great monuments of skill which the present age has produced, and which will ever redound to the honour of our land.

The vast engineering and railway works—bridges, vaults, arches, and tunnels, the new Houses of Parliament, the lighthouses, exchanges, town-halls, churches, warehouses, etc.—which have of late years been executed in this country under the guidance of distinguished architects, have given such an impetus to the study and practice of constructive masonry, that a race of masons has been reared amongst us of higher and more varied skill than have perhaps ever existed in England, and even this standard is daily being improved by the efforts made for the promotion of the education of working men.

LINEAR DRAWING BY MEANS OF INSTRUMENTS.

Walling.—The work of the mason in this department calls for the continual exercise of skill and judgment, for he has not, like the bricklayer, to deal with blocks of a uniform size, but with heavy masses of all shapes and sizes, whilst the length, depth, and height of the walls he is building are all fixed.

The best or highest sort of stone walling is the easiest to set, for in it all the stones are tooled or gauged to regular sizes, to range in courses, and to suit the thickness of the wall to be built; and the most difficult is really that which is deemed the commonest, being that in which rough blocks are used, the mason merely chipping them with his hammer or axe, and fitting them in the best way he can, so as to form a compact mass. This is called *rubble walling.*

All stone is to a certain extent brittle, and therefore great tact is required in setting these irregularly-formed blocks, so that the ends may not be supported whilst the space between them is hollow; or that the stone may not rest on one projecting part whilst the ends are unsupported. If long pieces are used, they must be propped up in every part, lest they should break across, and thus occasion the whole superstructure to give way. And thus, although the object of the mason should be to form as compact a mass as possible, still that is done with the greatest safety when the strength is equalised; and, therefore, he will act the most judiciously in breaking a very long stone into two or more short ones, and working them in that state; for, by this means, he knows how to support or counteract the effects of the extra joint which he makes. Joints which may ensue after the wall may be finished would be irremediable.

The mason must bear in mind that whatever may be the quality of the stone to be used, the wall should consist of as much stone and as little mortar as possible. If the stone be inferior in durability and power in resisting the effect of the atmosphere to what the mortar will be when hard, no ulterior good will be gained, besides the certain fact that the mortar will yield until it has set hard, and thus the block resting on it will be, during the interval, constantly changing its place as others are placed upon it. And if the stone be (as it should) the more durable material, the more of it entering into the wall the better. The stones, however, should never be allowed to actually touch each other, any more than in brickwork; for where this might be the case, the mortar, shrinking in drying, would throw the whole pressure on the prominent parts, and so cause unequal bearing.

Bricks are wetted before working, for if the surfaces be covered with dry dust the mortar will not adhere; and further, they would absorb rapidly all the water out of the mortar, instead of allowing it to set gradually. Stone, however, being of a less absorbent nature than brick, it is not so important that it should be wetted; nevertheless, it is better that it should be in at least a damp state when it is worked, the adhesion of the mortar being then more certain and complete.

APPLIED MECHANICS.—XVI.

BY ROBERT STAWELL BALL, M.A.,

Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.

THE HYDRAULIC RAM—CENTRIFUGAL PUMP—CHAIN PUMP.

We next consider the machines which depend upon the inertia of water, and first we shall discuss the very remarkable machine known as the hydraulic ram.

A diagram of the hydraulic ram is shown in Fig. 1. This figure will represent the principle on which the machine works.

P Q is a tube closed at the end Q, along which water flows, in the direction indicated by the arrow. This tube receives the water from a stream, and the object of the machine is to send a portion of the water up to a higher level. B is a valve, which is capable of being nicely adjusted; its weight is such that the ordinary pressure of the water beneath it is not sufficient to keep it closed. Thus the valve falls open, and the water flows out. The velocity with which the water flows is gradually accelerated while the valve is open, and the pressure consequently increases. When the pressure of the water attains a certain value, the valve B is pressed upwards and closed. The water which was flowing along the tube is thus suddenly checked. We have already learned that when a body is in motion it exerts a large force of resistance when its motion is checked. Water is no exception to this rule. The mass of water suddenly exerts a large pressure, and forces open the valve A. C is an air-chamber, in which the air is compressed; D is the pipe which carries the water to the height required. The pressure in the chamber C depends, of course, upon the height to which D is carried; but whatever be this pressure, the valve A will be forced open by the inertia, and a small quantity of water be driven into the air-chamber. When the water has come to rest, A shuts. The same operation is now repeated again; B drops open in consequence of the pressure not being sufficient, and the cycle again commences. Thus at each operation a small quantity of water is forced into the air-chamber C, and ultimately must ascend by the pipe D.

The inertia of water, which is so ingeniously applied in the hydraulic ram, has to be attended to in the fittings which are used in towns supplied with high pressure of water. Ordinary stop-cocks cannot be used on pipes in which the pressure amounts to 50 or 60 pounds upon the square inch. If the water be turned off suddenly, as it is by an ordinary cock, a rattling noise is heard, produced by the inertia of the water, and a violent strain is produced upon the pipes and fittings, which will sooner or later lead to rupture. The remedy is obvious. The force of inertia with which a body resists having its motion arrested varies according to the manner in which the motion is stopped. If the motion be stopped suddenly, the inertia is prodigious; if the motion be stopped gradually, the inertia is very small. The plan is, then, to cut off the water gradually. This is done by using a cock in which, by means of a screw, the aperture is closed or opened gradually.

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* Grinling Gibbons was of Dutch descent—if not, indeed, born at Rotterdam, concerning which there has been much dispute. He was born in 1648, and distinguished himself in carving at a very early age, when we find him living at La Belle Sauvage Yard, Ludgate Hill, the spot on which stands the works of Messrs. Cassell, Petter, and Galpin. Here he exhibited a pot of flowers carved in wood, so exquisitely delicate that the leaves vibrated as the coaches passed. He was subsequently recommended to Charles II., and executed a great portion of the carving in the chapel at Windsor. He also executed the carving in the choir of St. Paul's. He died in 1721.

An improved form of hydraulic ram is shown in Fig. 2. The water flows from the source along the tube A; at B is the valve called the stoppage-valve, which is analogous to the valve B in Fig. 1. The stoppage-valve is shown open in Fig. 2; it is supported by a stem, and when not held up by the pressure of the water drops downwards to a distance regulated by a screw and nut. When the stoppage-valve is down the water flows outwards above the valve, until the velocity is so much increased that the pressure is sufficient to close the valve. When the stoppage-valve is closed the inertia of the water compresses the air in the space C. This air is called the air-mattress. The pressure which is produced by the shock is sufficient to force open the valves E, E and discharge some of the water into the outer chamber. From the outer chamber the water rises in the ascension-pipe, G, in the manner already explained. The valves E, E are then closed, the valve B descends, and the process again commences. The use of the air in the chamber is to act as a spring; for were it not for this spring the shocks would derange the machinery. As the air is soluble in water, it is necessary to supply air to the chambers, in order to restore the quantity which is taken away; this is effected by a small valve, H, which opens inwards, and admits air when the other valves are closed.

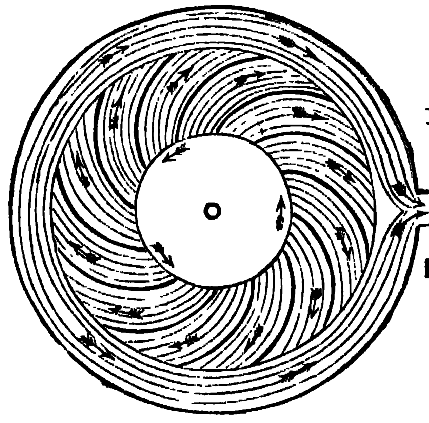


Fig. 3.

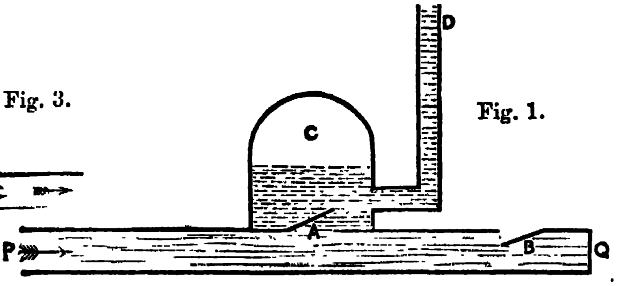
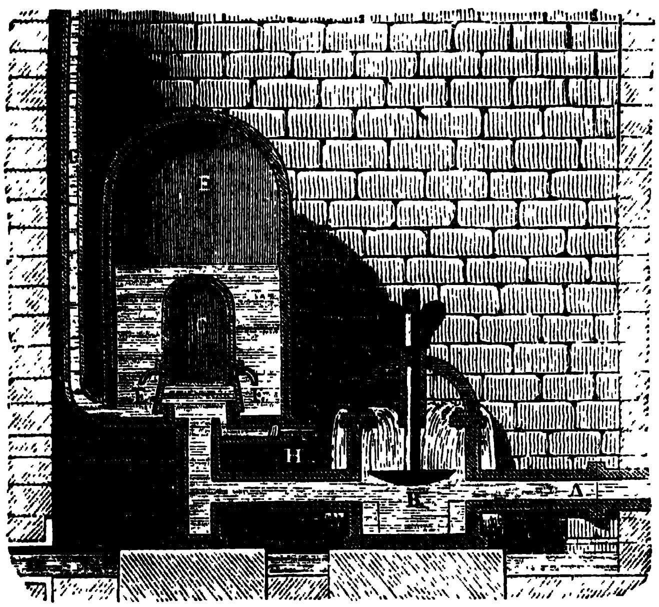


Fig. 1.

Fig. 2.

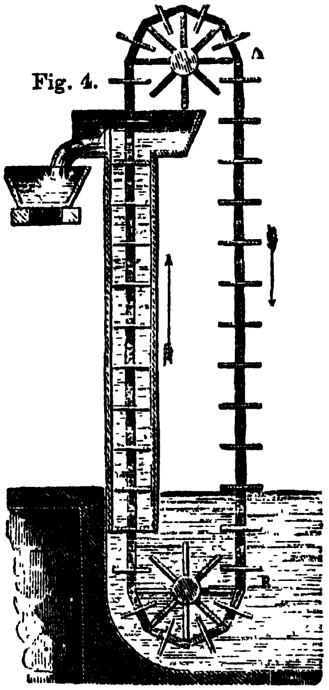


The hydraulic ram is periodic in its action, and so far resembles the pumps which we have been considering. It is principally employed when it is desired to raise a small quantity of water to a considerable height. It is frequently placed at the locks of canals, or similar situations, in which an abundant supply of water is available. The centrifugal pump, which we shall next consider, is a far more valuable machine than the hydraulic ram. It is capable, when worked with suitable power, of raising a vast body of water. It has, however, to be worked by a steam-engine, or other source of power, and so far is a more complicated machine than the hydraulic ram.

The centrifugal pump has very varied forms, which, however, all depend upon the same principle. We shall describe one of the most useful constructions, which is represented in Fig. 3. The water is introduced at the centre, O, from the lower reservoir from which the water is to be raised; from O the water enters by a series of openings into a wheel which is rapidly revolving in the direction of the arrows. This wheel is furnished with a series of blades perpendicular to its plane, thus dividing the wheel into channels, into which the water enters. When the water has entered the wheel, and becomes whirled round with it, centrifugal force drives the water along the channels to the circumference of the wheel, whence it finds an exit by the ascension-pipe.

In the construction of the centrifugal pump, particular care is required in the arrangement of the blades which form the channels along which the water flows; the efficiency of the machine depends greatly upon this point being attended to. What is required is to raise the water, and the energy of the engine which works the pump is to be devoted as far as possible to this purpose. The water, when it is raised, should be delivered with as little velocity as possible, for any velocity which the water possesses has been produced at the cost of the energy of the machine. Now the form of the blades is such that the velocity with which the water leaves the wheel is reduced to the smallest amount. The real velocity of the water is compounded of the velocity of the wheel with the velocity with which the water is flowing along the channels. By having the divisions nearly tangential to the circumference of the wheel the water is driven one way by its motion in the channels, and in the opposite way by the motion of the wheel; the consequence is that the water has really a motion only due to the difference of these velocities.

Fig. 4.



In Fig. 4 is represented what is called a chain-pump. This machine is very useful when a large quantity of water has to be raised. It consists of two wheels, the upper of which is turned by an engine, while the lower wheel is below the surface of the water. The chain which passes over the wheels is furnished with wooden boards, as shown in section in the figure. The water is raised by a rectangular case, which the wooden boards fit pretty accurately. This case goes below the surface of the water. As the boards are rapidly raised by the chain, the water is delivered from the top of the case.

TECHNICAL DRAWING.—XXXIX.

DRAWING FOR STONEMASONS.

RUBBLE—ASHLAR—RUSTIC WORK—ANGLE QUOINS, ETC.

What "bond" is, and the necessity for it, has been fully explained and illustrated in lessons on "Building Construction:" and bond is of no less importance in stone than in brick walling; only a few further observations will, therefore, be added. It has been explained (Vol. I., page 97) that walling is broadly classified into rubble and ashlar, and although these have been illustrated, it will be useful to insert the illustrations again.

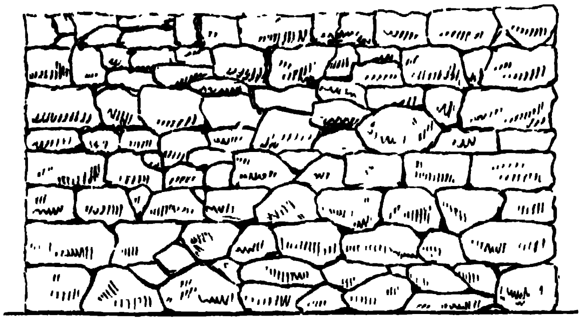


Fig. 358.

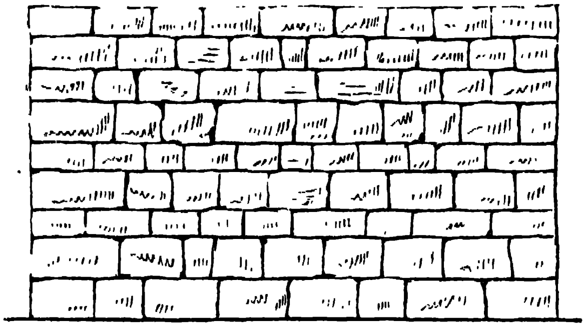


Fig. 359.

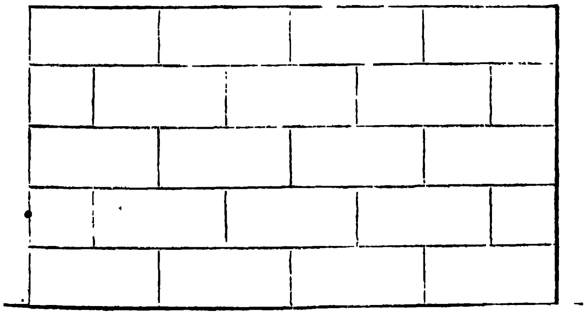
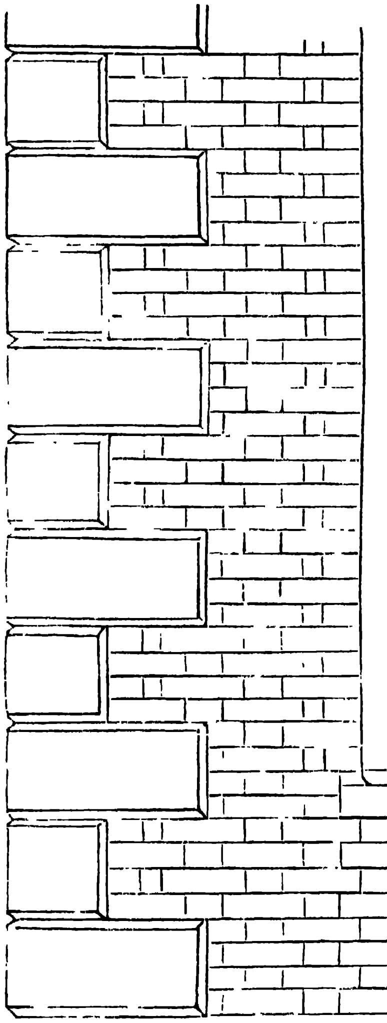


Fig. 360.

In rubble walls the joints, instead of being made to recur one over the other in alternate courses as with bricks, etc., should as carefully be made to lock, so as to give the strength of two or three courses or layers between a joint in one course, and one that may occur vertically over it in another. In bonding through a wall, or transversely, it is much better that many stones should reach two-thirds across, alternately from the opposite sides, than that there should be a few extending the whole way through, called "thorough stones." It is, in fact, much to be regretted that through a false economy walls are sometimes built of two thin scales, or faces, with thorough stones placed occasionally to tie them together, the core being made up of rubble and mortar. This mode of structure should be very carefully guarded against. There is no better test of a workman's skill and judgment in rubble walling than the building of a dry wall—that is, one without mortar—affords. Walls are frequently built with mortar, which would have fallen under their own weight without it before they reached the height of six feet, in consequence of their defective construction, thus showing that they are held together merely by the mortar, which is very seldom a sufficient bond.

The student will scarcely require any particular directions in drawing Fig. 358. The base-line and the vertical edge will, of course, be drawn first, then the stones in all their irregularity. The description of the mode of building will then be the best guide in drawing the example. The sketch should be done very lightly in pencil, and a common writing pen may be used for the purpose of inking.

Fig. 361.



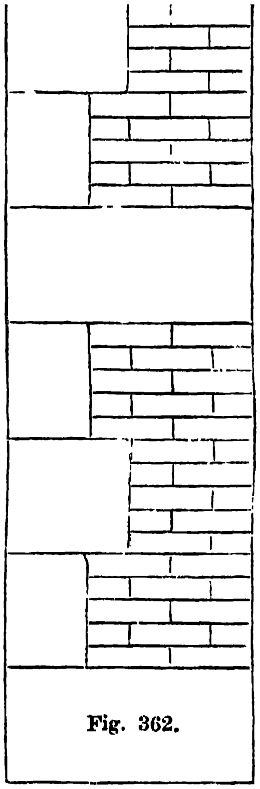


Fig. 362.

In drawing Fig. 359, coursed rubble, having drawn the base-line and vertical edge, the lines for the courses are next to be sketched, not *ruled*, for it will be remembered that the stones are rough dressed; the angle-quoins are, however, to be worked with greater neatness. All further information will be obtained from the preceding description.

Ashlar work (Fig. 360) must be carefully and accurately drawn, all the lines being ruled, and the widths of the stones measured. In drawing the whole elevation of a building, however, it is not usual to draw all the courses or single stones; a few lines freely but correctly drawn merely indicate the species of work employed. The method of using the various mathematical instruments, together with plain hints on linear drawing, have been given in "Projection" and "Building Construction," and, although we desire to make each of these courses of lessons complete in itself, it is obvious that to repeat such elementary information in this place would necessarily curtail the information we desire to give on higher branches. Now as the two subjects referred to must be considered as the basis of the present study, the reader is urged to take them up either before entering upon, or together with this; and as all practical art is based on geometry, the system on which it is intended to base our instruction should be worked as follows:—"Practical Geometry applied to Linear Drawing," "Projection," "Building Construction," and "Drawing for Stonemasons." By this method the student will learn:—(1) The properties of various forms employed, their relation to each other, and the methods of constructing them in the readiest and most correct manner. (2) The manner of obtaining views of them as solids, instead of merely as plane surfaces; the shapes of sections in various directions, the development of their surfaces, etc. (3) The subject of construction as a whole, and the adaptation of materials; also the various kinds of drawings used by builders, and the method of executing them, and will thus be prepared to enter upon the branch specially his own with that interest which grows from systematic instruction. It has been the fault of our artisans to be content with merely the amount of knowledge they have obtained from each other, and to take interest only in that which related to their own immediate branch. This limited view of knowledge is at all times to be reprehended, but it is especially wrong in the trades relating to building, in which the artisans have to work so closely into each other's hands. Thus the work of the mason and the bricklayer meet, and both must work in concert with the carpenter, so as to arrange for his joists, girders, wall-plates, partitions, roof-trusses, and lintels, templets, etc. The carpenter must arrange so that his work shall suit the plumber, whilst it must almost imperceptibly glide into that of the joiner, who must again understand the requirements of the glazier, locksmith, etc. etc. It will thus be seen that no man can be said to be truly efficient who only studies his own occupation up to a rigidly-drawn line, and the necessity for men being mutually helpful and working harmoniously together is thus practically shown.

When ashlar work is smoothed or rubbed so as to take out the marks of the tools used in working, it is called *plane ashlar*. When the surface is wrought in a regular manner, like parallel flutes, and placed perpendicularly in the building, it is called *tooled ashlar*; but when the faces are worked with a broad tool, without care or regularity, the work is said to be *random tooled*, and when wrought with a narrow tool it is called *chiselled* or *boasted*; when the surfaces of the ashlars are cut with very narrow tools they are said to be *pointed*. When the stones project from the joints, the ashlar is said to be *rusticated*; in this kind the faces may have either a smooth or broken surface.

When walls are not entirely formed of masonry, in the ordinary course of economic building, stone is frequently used for copings, cornices, string and blocking courses, sills, landing, steps, stairs, hearthstones, chimney-pieces, etc.; several of these will be found illustrated further on, and we proceed to speak of quoins.

Quoin-stones are gauged and wrought blocks with parallel beds and vertical faces, placed at the angles of buildings with the intention of adding to their strength and beauty; they are used either with brick or stone walls, and are, as a rule, made to project beyond that to which they are attached. The quoins are covered with the rest of the wall, if it be of stone, and are made to occupy the exact space of a limited number of bricks in a brick wall.

Rustic quoins.—In these the edges are either bevelled, or the margins recessed in a plane parallel to the wall. The recesses, which are at the joints, have, therefore, three sides—one in the plane of the wall, or parallel to it, and the other two generally at right angles to this. Rustic quoins were much used in brick buildings at the end of the last and beginning of the present century.

Rustic work is a mode of building in imitation of simple Nature, rather than allowing the work to have the appearance of having been carefully finished by art. In this style, the stones in the face, etc., of a building, instead of being smooth, are hatched or pricked with the point of an instrument.

The most coarse or common rustic work is that where the edges are simply cut about one-half or two-thirds of an inch round the margin, so as to be in the plane of the wall, or parallel to it; and the intermediate part is broken with the hammer, so that the protuberant parts may project generally about an inch beyond the margin.

The recesses of rustics either run with the horizontal joints only, and the projections have, therefore, the appearance of boards placed at small intervals, or sometimes the recesses run with both the horizontal and vertical joints; and, therefore, when placed in this manner, they have the appearance of projecting tablets.

Rustic chamfered is that class of work in which the faces of the stones are bevelled at an angle of 135° with the surface of the wall, and as the joints are at right angles to the faces the margins will also be at 135° with the joints, so that when two rustics come together the bevelling or chamfering will form an internal right angle.

Rustic work frosted is that in which the margins are reduced to a plane parallel to the plane of the wall, and where the intermediate part has the effect of ice with an irregular surface in protuberant parts.

Rustic work vermiculated is that where the margins are reduced to a plane parallel to the plane of the wall, and where the intermediate part of the stone or general surface is so formed as to have the effect of being eaten by worms.

Fig. 361 is an illustration of angle-quoins with bevelled edges, each quoin occupying the height of four courses of brickwork. The student is advised to adopt a definite scale to work to. The elementary examples herein given, although generally correct as to proportions, are not worked to scale, in order that the student instead of merely measuring and copying the lines, may absolutely *work* the subject. It will be remembered that the general size of bricks is a trifle less than 9 inches long, 4½ wide, and 2¼ thick. As there is, of course, some little space occupied by mortar, and for convenience of measuring, we here consider bricks 9 inches long, 4½ wide, and 2½ thick.

Having drawn the base-line and perpendicular, set off on the latter the heights of the quoins equal to four bricks, and draw horizontal lines; between each of these set off the heights of the separate courses of bricks. Now draw the vertical edges of the quoins, and also the double lines representing the chamfer, or bevel; the recesses at the outer edge and at the angles will be done by means of the set-square of 45°. The lines for the courses of the brickwork may now be drawn from the points in the perpendicular previously obtained. This plan is better than setting off the height of each course of brickwork from the bottom, in which plan the smallest error or inaccuracy is carried on and increased, whilst in the method here shown no error can extend beyond four courses.

In relation to the mixture of brick with stone ashlar in building, Sir Charles Pasley says that the stone should bear a definite proportion to the thickness of the brickwork in the wall, and mentions the British Museum, in which the stone is from 8 or 9 to 13 or 14 inches thick, in order to correspond with 1 and 1½ brick.

In stone pilasters, projecting from the face of a wall having a stone front, the courses are usually equal to two of the other courses in height, or even more, it being the custom to make such pilasters of much larger slabs than the other portion of the wall.

Door and window jambs are also generally made in much higher courses, or even sometimes in one piece, which is by no means unusual.

As the joints in brickwork, being more numerous, are more liable to be compressed, and consequently that portion of the brickwork is liable to settle more than the stone front of the wall, it is prudent never to hurry the brickwork, but to carry it regularly all round the building by portions of a small number of courses at a time.

Fig. 362 represents a section of a wall having a stone front backed with bricks. In this example it will be seen that the stones are of the height of five courses of brickwork, and eight or nine inches thick, with some of twelve or thirteen inches thick intermixed with them, and "thorough" or bond-stones at intervals; the total thickness of the wall is equal to three bricks.

The method of drawing this example is precisely similar to the last: no further directions are therefore necessary.

SEATS OF INDUSTRY.—XIV.

NORWICH.

BY WILLIAM WATT WEBSTER.

NORWICH, the capital of Norfolk, and a county in itself, is not only one of the most ancient cities, but it is also one of the oldest centres of manufacturing enterprise in Great Britain. Antiquaries disagree regarding the earlier history of the town. On the one hand, it is contended that Norwich was called *Caer Gwent* by the early Britons; that it was the capital of the Iceni; that Boadicea probably resided in the castle or fortress; and that it is the veritable *Venta Icenorum* of the Romans. On the other hand, it is maintained that Norwich rose out of the decay of an old Roman town, about three miles to the south, which, previous to the Roman era, was called Caistor, and is now known as Castor St. Edmunds. The latter, according to this view, was probably the *Venta Icenorum* of antiquity. There is a couplet to the effect that

> "Caistor was a city when Norwich was none;
> And Norwich was built of Caistor stone."

That a Roman camp existed at Caistor is not doubted; but it is alleged that it was placed there to guard the British settlement at Norwich, which was then a formidable stronghold. The name *North-wic* (the northern station or town) was conferred on the place by the Angles, the people who inhabited Northfolk and Southfolk; and by 575 it had become the capital of the kings of East Anglia. Records are in existence showing that the castle was occupied by Uffa, and that it was greatly improved by Anna, in 642, and by Alfred the Great, in 872. In the middle of the tenth century, Norwich was a large and wealthy town, divided into several distinct parishes; and in 1002 it was attacked and destroyed by the Danish fleet, under the command of Sweyn. It now became a Danish settlement, and the castle was rebuilt by Canute. At this period Norwich appears to have been an important fishing-town; and in the reign of Edward the Confessor it was a large, affluent borough. In Domesday Book it is stated that the city or borough had a mint, 1,320 burgesses, 25 parish churches, and from 800 to 900 acres of land. William the Conqueror bestowed the castle on Roger Bigod, one of his Norman followers, who is believed to have built the present keep; and it remained in the possession of his descendants till the reign of King John, when it was finally surrendered to the crown in 1224. In the reign of William Rufus, the bishopric of the East Angles was transferred from Thetford to Norwich; and the first stone of the celebrated cathedral was laid by Bishop Herbert, in 1096, the edifice having been completed by William Middleton, in 1284. Here we may note a remarkable natural change which took place in the vicinity of Norwich between the fifth and the middle of the eleventh centuries. Prior to the first of these dates, the town had been washed by an arm of the sea; but at that period the water began to recede, and by the year 1050 the channel had assumed the appearance it now presents. Henry I. granted a charter to Norwich containing the same franchise as London enjoyed; and the government of the city was then separated from that of the castle, the chief dignitary being styled *præpositus*, or provost. Up to this time Norwich would appear to have owed its chief importance to the fact of its being a stronghold; and its strength was greatly increased by Edward I. (Longshanks), who built walls round the town. The same monarch, two years later, gave the city the privilege of sending two members to Parliament; the franchise being vested in the freemen and freeholders not in receipt of alms, down to the passing of the Reform Act of 1832.

In the reign of Henry I. a colony of Flemish artisans settled at Worstead, in Norfolk; and this event may be considered the starting-point of the industrial history of Norwich, which thus dates from the beginning of the twelfth century. It is believed that these colonists were the first to introduce water-driven corn-mills, wind-mills, and fulling-mills into England, and that they revived the spinning and weaving of long woollen stuffs, and the art of building in brick, which had not been practised in the country since the withdrawal of the Romans. Portions of Flemish brickwork may still be seen in several of the old churches of Norwich and Worstead. There was a considerable number of Jews in the city of Norwich about the middle of the twelfth century, as well as in nearly all the principal seats of commerce in England, and especially in those situated on the east coast, which offered facilities for trading with the Continent. The Hebrews were wealthy, and their wealth excited the jealousy of the people. On the accession of Richard Cœur de Lion, in 1189, the Jews in London were massacred in great numbers by an infuriated mob, and the work of extermination was repeated at Norwich and other towns where they had settled, in spite of the attempts made by the king to protect them.

In 1328, Edward III. made Norwich the staple town of Norfolk and Suffolk for the sale of wool, wool-fells, and cloths; and about the year 1336 another and a larger body of Flemings migrated to the city, and added the weaving of worsted into cloth to its other industries. After this date the town appears to have made rapid progress, although its prosperity was frequently retarded by insurrections, plague, famine, and fires. During the reign of Richard II., discontent prevailed throughout the kingdom, and popular risings became general. Norwich was plundered and devastated by armed bands, which are said to have numbered collectively 80,000, led by Litester, a dyer. In 1403, Henry IV. separated the city from the county, constituting it a county by itself, and granting its inhabitants special and peculiar privileges. The doctrines of the Reformation were adopted in Norwich as early as 1422, and several Wickliffites, or Lollards, were executed there for heresy. By the year 1533 there were in Norwich twenty independent guilds, representing a much larger number of trades. The cloth-cutters, fullers, woollen and linen weavers, and wool merchants constituted one corporation; tailors, broiderers, hosiers, and skinners were united together in one guild; while the wax-chandlers, barbers, and surgeons formed a single corporation. It would appear, from an Act dated 1541, that the trade of Norwich had declined during the reign of Henry VIII. After stating that "among other cities, shires, and towns, having private commodities, the city of Norwich hath always heretofore been maintained and preserved, and that the poor men, and other dwellers and inhabitants, godlily, honestly, and virtuously brought up in the same, have been occupied and exercised by a commodity growing and rising only within the said city, that is to say, the making and weaving of worsteds and other cloths, which have been made and woven of yarn spun of the wool growing and coming of sheep bred only within the county of Norfolk, and in no place else; and whereas this trade has been of late craftily and deceitfully taken away by men buying up the wool of Norfolk, and sending it in a raw state to be manufactured in France, Flanders, and other places beyond the seas, and by reason thereof the city of Norwich and other towns in Norfolk are not only most likely to be brought to utter ruin and decay, but the inhabitants to be destitute of any way to get an honest living by," this measure enacts that no Norfolk wool shall henceforth be exported or worked up out of the county, under a penalty of forty shillings for every pound of yarn so exported or worked up. But this Act did not revive the drooping prosperity of the town, and the woollen trade remained in a depressed state for upwards of twenty years after it began to be enforced.

In the year 1549, the enclosure of certain commons and waste lands near Attleborough and Wymondham led to a rising similar to the Jacquerie in France, and the peasants' war in Germany. Under the leadership of a bold and resolute artisan, named Robert Kett, or Knight, a tanner, and his brother William, a butcher, the insurgent peasants and workmen laid siege to the city of Norwich. A camp was formed, and forces numbering 16,000, and including many of the city people, were collected. The hostilities continued for a month, and the country round Norwich was pillaged and laid waste. At length an entrance into the city was effected, and the mayor and several members of the corporation were taken prisoners, and carried to the camp as hostages. A strong body of troops, under the command of the Marquis of Northampton, marched to the relief of Norwich, but suffered defeat. The Earl of Warwick and his son, Robert Dudley, Earl of Leicester, were next sent against the insurgents; and after a conflict lasting two days, succeeded in defeating them, both sides losing about 3,000 men. Three hundred of the ringleaders of the rebels were executed on the spot, and the two Ketts were sent to the Tower of London, to meet the same fate. Again the Flemings poured into Norwich, and revived the prosperity of the town. The persecutions of the Duke of Alva drove large numbers of Huguenots to seek refuge in England, and upwards of 4,000 of them settled in Norwich about the year 1561. But they had only fled from one form of persecution to encounter another, hardly, if at all, less cruel. The following paragraph from Mr. Smiles's "Huguenots" powerfully recounts that portion of the history of Norwich at which we have arrived:—"Although Norwich," he says, "had been originally indebted mainly to foreign artisans for its commercial and manufacturing importance, the natives of this city were among the first to turn upon their benefactors. The local guilds, in their usual narrow spirit, passed stringent regulations directed against the foreign artisans who had originally taught them their trade. Jealousy was excited, and riots took place against the Flemings, many of whom left for Yorkshire, to lay the foundation of the fortunes of several towns there: and Norwich, left to its native enterprise and industry, fell into stagnation and decay. The population diminished, riots were frequent among the distressed workpeople, and it was even mooted in Parliament whether the place should not be razed. Then the corporation determined to call to their aid the skill and industry of the exiles. In 1564 a deputation of citizens waited on the Duke of Norfolk, who succeeded in inducing 300 Dutch and Walloon families to settle in Norwich at his charge, and carry on their trades under a licence from the queen (Elizabeth). They restored the prosperity of the city; and in the course of a few years, 3,000 foreign workmen were found in Norwich, and many entirely new branches of industry were introduced and in operation. Besides sayes, bayes, serges, arras, mouchade, and bombazines, they introduced the striping and flowering of silks and damasks, which shortly became one of the principal branches of trade in the place. The manufacture of beaver and felt hats, which were formerly imported, was also successfully established at Norwich; and Anthony Solen introduced the art of printing, for which he was awarded the freedom of the city. Two potters from Antwerp also started a pottery there." But the antipathy of the citizens of Norwich towards the foreigners was not yet extinguished; and about the year 1570 a formidable conspiracy to expel them from the city was discovered, and its leader and instigator, John Throgmorton, was seized and executed, after which the refugees were allowed to follow their callings in peace. The foreign artisans enjoyed the favour of Elizabeth, who wrote from Greenwich in this same year, strongly expostulating with the inhabitants of Norwich against their foolish jealousy towards the authors of their prosperity. A census of the foreigners in Norwich, taken soon after this date, showed that they numbered 4,000, including women and children, and ten years later they were found to have increased to 4,679. Another immigration of foreigners into Norwich took place towards the end of the seventeenth century, the artisans in this case coming from France, and being skilled in the manufacture of silk goods, such as lustrings, brocades, tabinets, and velvets, while others made cutlery, clocks, and watches. In the Civil War, Norwich declared for the Parliament, and was occupied by its forces till Cromwell became protector. In addition to its great cathedral, the ecclesiastical history of Norwich is remarkable from the number of convents and other religious establishments that have flourished there, the funds of which have in most cases been diverted to charitable uses, and placed under the management of the corporation.

The manufacture of cotton was introduced into Norwich in 1784, and the close of the last century seems to have been the period of greatest prosperity in the history of the town. It has been estimated that the value of the goods exported from the city at that time to the East Indies, Russia, and other countries (consisting chiefly of camlets and camletees, callimancoes, worsted satins, figured stuffs, lustrings, damasks, and shawls) amounted annually to £1,000,000, or about one-fourteenth part of the British manufactured goods exported at that period. Since that date Norwich has been outstripped by rival manufacturing towns in Lancashire and the West Riding of Yorkshire, which have enjoyed greater advantages, on account of their proximity to rich coal-fields and the absence of corporation privileges. Many articles formerly peculiar to Norwich are now manufactured at cheaper rates elsewhere; and the greater part of the yarn worked into fabrics at Norwich is spun at Bradford. The worsted manufactures of the West Riding are now far more extensive and valuable than those of Norfolk. In 1719 a new silk and worsted fabric, called Norwich crape, was invented, which rapidly became so fashionable, that during Walpole's administration court mourning entirely consisted of it. There were about 1,000 persons employed in the mills for throwing silk at Norwich in 1810.

The close and influential connection of the Gurney family with Norwich throughout many centuries entitles them to a place in a sketch of that town, however brief, and their story forms an important chapter in the history of British commerce. As Mr. Bourne has remarked, in his "English Merchants," we see in the Gurneys "the almost solitary instance of an ancient family that in later times has not been ashamed to engage in commerce, and has drawn from it a dignity as great as any that could come from lengthy pedigrees and the traditions of bygone ages." The founder of this house in England, Hugh de Gournay, Lord of Gournay and Le Brai, held an important command at the battle of Mortimer, in 1054; and coming to England with the Conqueror, in 1066, was awarded large grants of land in Norfolk and Suffolk. It would appear that the first of the family who settled in the town of Norwich was Edmund Gournay, who, in the time of Edward III., held an office corresponding to the recordership. Since that date some members of the family have always resided at Norwich, and several of them have greatly contributed to its prosperity. Towards the close of the seventeenth century, John Gurney was for thirty years a famous and highly successful merchant in Norwich. After serving an apprenticeship to a cordwainer in the town, and suffering three years' imprisonment in Norfolk Gaol on account of his having in his twenty-third year adopted the doctrines of the Society of Friends, John Gurney started in business as a merchant and manufacturer, and, at a later period, as a sort of banker or money-lender. He supplied silk to the Palatines and other foreign refugees in Norwich, and built a silk-mill there, on the model of the celebrated silk-mill of Sir Thomas Lombe, at Derby. When he died, in 1721, at the age of sixty-six, John Gurney left a considerable fortune and a very profitable business to his sons, John and Joseph, in the accumulation of which he had been ably assisted by his wife, who, it is alleged, was the real founder of the commercial greatness of the Norwich Gurneys. The sons carried on the business with great success; and John became known in his day as "the famous advocate of the weavers," he having been instrumental in obtaining the passing of an Act dated 1721, "to preserve and encourage the woollen and silk manufacturers," which prohibited the use or sale of cotton clothing, under a penalty of £5 for the offence of weaving, and £20 for selling any cotton garment. It was the two sons of the "weaver's advocate," John and Henry Gurney, who founded the Norwich Bank, they having, in 1770, converted their old dwelling-house, in Saint Augustine's parish, into a banking-office, and from that date devoted themselves exclusively to banking transactions. In 1779 the business descended to Bartlett Gurney, Henry Gurney's son, who removed it from the original premises. Three cousins and others were adopted as partners, and on the death of Bartlett Gurney, in 1802, the concern came into their hands. Of the three cousins the most remarkable was John Gurney, born in 1750, the father of Elizabeth Fry, Lady Thomas Fowell Buxton, Joseph John Gurney, the philanthropist, and Samuel Gurney, the millionaire. It was about the year 1800 that the celebrated house of Richardson, Overend, and Company was founded, through John Gurney's assistance; and in 1807 the firm was greatly strengthened by the introduction of his son Samuel as a partner. Until the death of John Overend occurred, however, the connection of the Gurneys with the firm was kept secret, but after that event it assumed the world-famous title of Overend, Gurney, and Co. The story of this firm hardly comes within the scope of this paper; but, to complete the outline, it may be mentioned that the establishment, which had been left in a position of almost unexampled wealth and influence by Samuel Gurney, who died in 1856, one of the richest men in England, was reorganised as a joint-stock company, under the "Limited Liability Act," in 1865, and failed on the 18th of May, 1866.

In addition to its worsted and silk factories, Norwich contains iron and brass foundries, snuff-mills, vinegar-works, dye-works, corn-mills, malt-houses, breweries, and oil and mustard mills; and of late years the manufacture of ladies' boots and shoes has been extensively carried on there; this having, indeed, become one of the staple trades of the city. In the latter branch of industry women and children are principally employed, but a considerable number of men are engaged in it as well. The making of agricultural implements is also prosecuted at Norwich with great success. Since 1833 the commerce of the city, which consists chiefly in the export of manufactured goods and agricultural produce to London and other ports—its foreign trade being inconsiderable—has been greatly facilitated by means of canals connected with the Lowestoft navigation, which give vessels drawing ten feet of water direct access to the town from the sea.

Norwich is situated on the river Wensum, immediately above its junction with the Yare, and is twenty miles W. of Yarmouth, and ninety-eight miles N.N.E. of London. Seen from a distance, its appearance is very striking; and it has long been called "the city in an orchard," owing to the unusually large proportion of garden-ground which surrounds it. Portions of the old walls and towers are still in existence, and there are many objects of interest to the antiquary in the city. The cathedral, which did not assume its present shape till the sixteenth century, is one of the largest and finest ecclesiastical edifices in the kingdom. The style is almost purely Norman. It is cruciform in structure, and from the intersection of the cross formed by the nave, choir, and transept, springs a lofty Anglo-Norman tower of four stories, highly ornamented, and surmounted by an elegant spire, rising 315 feet from the basement of the church. The west entrance is extremely beautiful, notwithstanding that the more salient ornaments have begun to moulder away, and it is from this point the best view of the pile can be obtained. The interior of the cathedral is exceedingly imposing and grand, but the architecture is of various periods, from the Anglo-Norman to the English Perpendicular, and modern alterations have not in all cases been improvements. The roof is divided by fourteen semi-circular arches, and there are 328 elaborately sculptured figures of Scriptural subjects among the decorations. Its cloisters are also remarkable, both for their dimensions and embellishments. Near the cathedral are several ancient and valuable specimens of architecture; and the city contains about forty churches, and about twenty-two dissenting chapels and other places of worship. St. Peter's, Mancroft, is a large and handsome cruciform edifice, dating from the fifteenth century, with a noble tower ninety-eight feet high, containing a peal of twelve bells, considered one of the finest in England. Among the charities of Norwich, the most noteworthy is St. Giles's Hospital, which is maintained by rents and other property yielding an average annual revenue of some £7,000. It provides clothing, food, and a small stipend for 165 inmates, exclusive of servants. The Free Grammar School of Norwich was founded by Edward VI., and possesses endowments amounting to about £200 per annum, and a fellowship at Caius College, Cambridge. There is a public library in the city containing 20,000 volumes, and the library of the Norwich Literary Institution consists of 15,000 volumes. In 1821, Norwich had 50,288 inhabitants; in 1831, 61,110; in 1851, 68,706; in 1861, 74,891; and in 1871, 80,390. Many of the streets are new and handsome, but, as a whole, the city is indifferently built. The houses are nearly all of brick, and in the older quarters are more remarkable for their age than for their beauty or comfort. There are in the town and vicinity ten bridges; and the market-place is one of the largest in Great Britain, being 600 feet long, by 340 feet in width.

FARMING AND FARMING ECONOMY.—III.

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MITIGATION OF PHYSICAL CONDITION OF SOILS—MANURES—FARM-YARD MANURE, GUANO, SUPERPHOSPHATES, ETC.

Soil, like other substances, possesses physical properties and a chemical constitution. Physical properties have relation to those features which are discernible to the senses in any body, simple or complex. Thus a piece of chalk is white, comparatively soft, has a definite specific gravity, and certain relations to heat, light, electricity, moisture, etc. In the same manner the soil, whether it bear the character of a retentive clay or a blowing sand, has physical attributes well worthy of the farmer's consideration. Its colour exerts an influence upon its temperature; its tenacity has an important effect in its relations to moisture and to growing plants, as well as upon every tillage operation; its relations to heat and moisture have much to do with its fertility; while if we take into consideration the physical conditions under which it is placed, we shall see the importance of climate, of inclination or slope to the north or south, and of the relation of soil to subsoil. The study, therefore, of the physical properties and conditions of soils is most important, especially as means exist for, to some extent, modifying them.

As drainage, clay-burning, and mixing are processes by which the physical condition of soils may be mitigated, so the application of manurial substances is the means by which their chemical condition may be improved. In other words, while the soil is put into the best possible mechanical condition by the first class of improvements, it is enriched and stored with plant-food by the second. Although the means of improving land may be thus divided into two classes, they imperceptibly glide into each other. Thus, while marling exerts a direct effect in altering the physical condition of a soil, it also enriches it with valuable mineral constituents. Even farm-yard dung, the typical manure of so many farmers, may be shown to act both mechanically and chemically upon the soil. The mechanical action of ordinary farm-yard dung was strongly believed in by Jethro Tull, who attributed its usefulness entirely to its causing the further disintegration of the soil during its own decay. Numerous other substances applied to land exert this double effect, and thus improve the physical condition of the soil while they increase its store of plant-food. There is, therefore, some danger of confounding these two actions with each other, and it becomes necessary to clearly define the meaning of the term "manure." The usual dictionary explanation of the word is scarcely strict enough for our purpose; and we cannot agree with Webster that a manure is anything which fertilises land, for if this were the case then would the ordinary tillage operations of the farm come under the definition. Manuring consists in applying substances to the soil which subsequently may be employed by growing plants in building up their tissues. The repeated growth of crops removes plant-constituents from the soil, which it is found necessary to restore by the use of manures. It is of importance to bear in mind that the value of a manure depends upon the extent to which it is able to replace the constituents removed from the soil by crops. It is, therefore, no matter of wonder that farm-yard manure, composed as it is of the excrements of highly-fed animals and decaying vegetable matter, should be a highly-valued fertiliser. Such a substance, when made under the most favourable conditions, contains in an available form every necessary constituent of both corn and straw, and is eminently adapted both to keep up and increase the fertility of land. Other substances have of late years been introduced to the notice of the farmer for the same purpose, and the use of artificial manures is one of the principal features of modern farming. Artificial manures owe their origin to the light which chemistry has thrown upon the practice of agriculture. No sooner was it discovered that fertility was in a considerable degree due to the presence of certain definite substances in the soil than the idea arose that fertility could be maintained by the artificial application of those substances. Hence ammonia salts, nitrates, phosphates, potash, and magnesia salts began to be successfully employed in agriculture, and the manure trade became an important part of our commercial life. Artificial manures have supplemented, and to some extent superseded, the use of farm-yard manure. It is important to bear in mind that the value of a manure consists in the amount it contains of a few chemical substances. This is a lesson which farmers are somewhat slow to learn; and a sort of superstitious veneration still exists for farm-yard dung, composts, vegetable and animal matter, or, in fact, anything which combines bulk, "greasiness," and a bad smell. It is, however, only chemical analysis which can truly indicate the quality of a manure; and the basis upon which the chemist makes his estimate is the per-centage of certain fertilising elements. The question of farm-yard and other "natural" manures, *versus* "artificial" fertilisers, is capable of scientific solution. Farm-yard dung is always a safe, although occasionally an extravagant, application to land. It is difficult to make a mistake in using it; whereas the proper use of artificial manures requires considerable knowledge of the requirements of plants and the nature of soils. That fertility may be maintained and increased by artificial manures alone has been fully proved at Rothamsted, by the long-continued experiments of Mr. Lawes and Dr. Gilbert upon the growth of wheat. This is a case in which wheat has been grown, under a variety of circumstances, upon the same land consecutively for twenty-eight years. The field is divided into plots, each of which has received a different treatment; and from all of them both straw and grain have been constantly removed for the period above named. A plot constantly unmanured has given a low average of 14¾ bushels per acre; a second, manured annually with 14 tons per acre of farm-yard manure, 35¼ bushels per acre; a third, manured with an artificial combination of all that the plant requires, has yielded an average of 36½ bushels per acre, and has been greatly improved in productive power since the commencement of the experiment. The above averages are for seventeen years, between 1852 and 1868. Similar trials upon barley for the same period confirm the fact that a soil may be fully supplied with manurial matter by means of artificially produced chemical substances. Hence we have good reason to believe that the boasted dictum of "the more stock the more corn" is incorrect, and that there is no essential relation between feeding animals and growing corn-crops.

Manures have been divided into two classes—*general* and *special*. A general manure is a substance containing all the necessary constituents required by growing plants. It is therefore able to keep up and increase the fertility of a soil. A special manure, on the other hand, does not contain every necessary constituent, and occasionally only one or two of them. Such a substance is, in a qualified sense, exhausting to the soil when frequently applied. Take, for example, the two cases of farm-yard manure and "nitrate of soda," the first a general, and the second a special manure. Repeated dressings of the first would enrich the soil; but repeated applications of the second would, by stimulating the growth of the crop, tend to rob it of phosphoric acid, potash, and all valuable constituents except nitrogen. Nitrate of soda contains no phosphoric acid or potash, and these being removed in greater quantity by plants manured with the nitrate, repeated dressings of this substance would be followed by a diminished store of other plant-constituents. This is no reason for discontinuing the use of nitrate of soda as a manure, for a good farmer will supply phosphoric acid and other constituents in due course, and the supply of all necessary manurial substances will be kept up in the soil.

Special manures are useful under three classes of conditions. First, when applied to crops which have special requirements, as, for example, when potash is used for potatoes, or common salt for mangel-wurzel; secondly, when a soil is deficient in some particular constituent, such as lime or magnesia, the addition of which will cause it to approach nearer to the standard of a perfect soil; thirdly, when it is employed to realise a store of fertility already accumulated in the soil. This last case is best illustrated by a wheat-crop growing upon land in high condition from previous manuring. Here, nitrate of soda may be applied with great advantage, as it will at once cause the wheat to grow vigorously, and to remove from the soil plant-food which would otherwise have remained dormant. Thus may nitrate of soda and other special manures be employed as a means of quickly recovering the farmer's capital from the land.

It may readily be shown that the continued use of a general manure is not always economical. If, for example, we continue year after year to dress a field with farm-yard manure, while we add to it all that is necessary, we are probably also adding more than is necessary. Certain substances will accumulate in the soil in excess of what is needed; and a rational system will point out the advantages of using some special manure, so as to realise the store of fertility now present.

Farm-yard manure, the oldest, and probably still the most important manurial substance employed in agriculture, is exceedingly variable in its composition. Its basis is the food and litter with which the animals producing it are supplied, and it will be found to vary in quality according to the circumstances under which it is formed. Thus the age of the animal is important, the manure of young, growing cattle being inferior to that of older stock; the kind of animal, whether it be a horse, ox, sheep, or pig; the condition of the animal as to fatness or leanness, and the quality of the food given, all exert their influence. The proportion of litter to the solid and liquid excrements, the amount of shelter from rain and snow during its formation, and the after treatment to which it is subjected, all bear upon the value of farm-yard manure, and render the formation of the best dung a complicated question. The best farm-yard dung is obtained by mixing the manure produced by various animals maintained on the farm. Horse-dung is proverbially hot, being comparatively dry and rich, and quickly ferments and becomes mouldy. Pig-manure, on the other hand, is considered cold in its nature, and the excrements of both these animals are improved by being mixed with that of cattle. These points should be attended to in the designing of farm-buildings, and the horse-stable and pigsties should be so arranged that the dung and litter may be conveniently spread over fold-yards. Sufficient shed and loose-box accommodation should also be provided; and the open yards must be "troughed," so as to protect the manure from rain, and economise litter as much as possible. By these means straw is saved, and a good quality of manure is obtained. With regard to the staple manure of the farm—that produced by horned cattle—the best is made in loose boxes, or well-protected and small yards, by fatting cattle fed upon cotton or linseed cake, meal, and a few roots.

It was formerly the almost universal custom to cart the dung from the fold-yards, place it in heaps near the field for which it was destined, and to turn it once or twice, so as to promote decay. The advantage of allowing this decay to take place in the land is now so universally allowed that most good farmers prefer to cart a large proportion of their yard manure direct to the fields in the autumn, and there to plough it in. This is a great improvement upon the older practice, especially upon the heavier classes of soils, which derive considerable advantage from the decay of vegetable matter within them.

Farm-yard manure is useful for all crops, and is applied at almost all periods of the year. Immediately after harvest, and throughout autumn, it is carted on to the land intended for the next year's root-crop; in winter it is applied to young seeds; in spring, to potatoes and mangel-wurzel; in summer, to various root-crops, bare fallows, and land intended to be broken up for wheat. The major portion is usually applied to the fallow or root-land; but many good agriculturists prefer to cart a considerable amount on to clover and other leas, in anticipation of wheat. Half the yard manure may be well employed for this purpose, and it will exert the maximum effect when applied to young seeds in the winter or early spring. This secures a good hay-crop, and it has frequently been observed that such a crop is followed by a full crop of wheat. The remainder of the yard manure will be best applied to the root-land from which it is intended to cart the produce to the folds; and the roots which are to be eaten on the ground by sheep may be grown with the help of superphosphates and other artificial manures.

Of late years much attention has been directed to the best method of using straw. It has been shown that this material may be employed for feeding purposes, and that it is too valuable to be employed for litter alone. Accordingly, the greatest economy ought to be observed in using it for this latter purpose, and buildings should be provided to prevent its waste. Some advanced farmers, like Mr. Mechi, have adopted a system of feeding cattle and pigs upon sparred floors, and so have rendered the use of straw as bedding unnecessary. In such cases the excrements of the cattle fall through between the spars which constitute the floor of the sheds or boxes, and are washed, by means of water, to a large tank, from which they are pumped as liquid manure to all parts of the farm. In order to carry out this plan, iron piping and hydrants are required to convey the liquid manure over the land, and also an engine to complete its distribution. Wonderful results have been obtained at Tiptree Hall by the use of such liquid manure, but it is by no means proved that there is any true economy in the conversion of solid excrements into the liquid form. In ordinary farming it is the opinion of most practical men that the best plan is to shut out all extraneous water by properly arranged buildings, and to convert the whole solid and liquid excreta into solid manure by the use of a sufficient amount of litter. Straw need not be exclusively used for this purpose, although it will be long before, even in well-farmed districts, its function as litter ends. Mr. Randell, of Chadbury, recommends burnt clay as a means of absorbing dung and urine, and other agriculturists have employed sawdust, potato-haulm, and other porous materials obtainable. Another difficulty in finding a better use for straw is the absurd restrictions prevailing in agreements for letting land. The farmer is very often forbidden to sell straw; and should his farm be adapted especially for corn-growing, he has a large surplus of this substance, which he is only too glad to crush into farm-yard manure. So far, therefore, from economising straw, it is not uncommon to find farmers purchasing cattle for the avowed purpose of "crushing down the straw," and this in advanced districts. Landlords would consult their own interests by removing such vexatious restrictions from intelligent tenants, and allowing them to sell the produce of their farms in the best market; and it is absurd that straw, which commands a high market value, should, through a foolish clause in a lease, be trodden into inferior farm-yard manure.

There are other sources of manure upon farms than that of the domestic animals maintained upon it. Every kind of vegetable refuse, such as weeds, hedge-clippings, haulm, leaf-mould, etc., should be collected together and mixed with lime, at the rate of one load of lime to five loads of refuse. The whole should be turned at least twice, and subsequently carted on to the land—not, however, until the roots and seeds of weeds have been killed by contact with lime and sufficient turning. Such a combination of lime and vegetable refuse is what is termed a "compost-heap," and is seen wherever neat farming is carried out.

Farm-yard manure and composts are staple manures; but the requirements of modern agriculture introduce a large class of substances to our notice which, under the names of "hand," "portable," "artificial," and "special" manures, play an important part in rural economy. Volumes might be written upon the composition, uses, and effects of those manures, and it is no easy task to give even a general notion of their application to the numerous soils and crops for which they are specially adapted. The terms *nitrogenous* and *mineral* have been somewhat unphilosophically employed in classifying these fertilisers. The first term requires no explanation. It embraces all manures in which nitrogen plays a conspicuous part, such as many guanos, nitrate of soda, sulphate and other salts of ammonia, blood manure, rape-cake, fish manure, animal refuse of all kinds, etc. "Mineral manures" comprise superphosphate of lime, salts of potash and magnesia, lime, and, in general, substances which supply the fixed or non-volatile parts of plants. Every plant-constituent is essential, but all are not equally abundant. The two elements of plant-life which up to this time have been most in demand are phosphoric acid and nitrogen. Accordingly, phosphatic and nitrogenous manures command a high price, and are very largely employed by farmers. Of late years increased attention has been bestowed upon potash salts, but they are not yet so familiar to agriculturists as the two former classes of manures. Phosphoric acid is supplied in "superphosphates," manufactured from bones or natural mineral phosphates, such as apatite and phosphorite. It is sold at from £5 10s. to £7 per ton, and is applied at the rate of from 3 to 6 cwt. per acre. These phosphatic manures exert the greatest influence upon the root-crops of the farm—*i.e.*, turnips, swedes, and mangel-wurzel; they are also effective upon clovers. Nitrogenous manures are more peculiarly adapted for graminaceous plants, such as the meadow-grasses and the cereals, upon which they exert a most marked effect. Thus the two principal plant-constituents needed as applications to growing crops are added to the land at different periods of the "rotation," and the field is maintained in a fertile condition. Reverse the order, and top-dress wheat with superphosphate, and swedes with nitrate of soda, and the manure in both cases will be all but wasted.

We conclude these remarks upon manuring with a short summary of the manures usually employed, the crops for which they are most suitable, the quantities usually applied, and the season of the year at which they may be used with the greatest effect.

Farm-yard manure, useful for all crops; applied at the rate of from 10 to 30 tons per acre, at various seasons of the year, according to the requirements of each crop.

Rape-dust, mustard, cotton, and *castor-cake* have all been used, but especially the first. They are rich in nitrogen, and contain valuable "mineral" constituents; they are applied to turnips and cereals with success, and should be distributed during damp weather in spring and summer, at the rate of 5 to 7 cwt. per acre.

Green Manuring, or Manuring with Fresh Vegetable Matter.—Spurry, white mustard, and turnips are employed in this country; and rye, clover, buckwheat, white lupins, rape, borage, etc., have been employed abroad. Sow at the end of harvest, and after two months plough in, as a preparation for winter wheat. It has been recommended to sow and plough in three successive crops of white mustard, as a means of both enriching and cleaning land.

Sea-ware, or *sea-weed*, is washed ashore in vast quantities on some portions of the sea-board, and forms a very valuable dressing for young wheat and grass-land. Its non-fibrous structure allows of a rapid decay, and its large per-centage of nitrogen makes it a valuable manure. It is of greater value per ton than farm-yard dung. This manure is much used in the western counties of England in manuring for potatoes. After having been carted from the sea-side to some convenient spot, it is allowed to lie and rot before it is carried on the ground. The smell of the rotting sea-weed is most offensive; but although it is most unpleasant to the olfactory organs, it is not considered to be unhealthy.

Composts have been already referred to.

Guano, or the excrements of sea-fowl, amassed under favourable conditions for many ages, varies in composition according to the climatical influence under which it has been formed. Peruvian guano is highly nitrogenous, and contains also a large per-centage of phosphates. Guano is applied as a top-dressing to cereals and grasses, and in the north of England and Scotland is largely employed in turnip cultivation. It is applied at the rate of 2 to 4 cwt. per acre as a top-dressing, and in conjunction with superphosphate and farm-yard manure for root-crops.

Hair, skin, horn, wool, blood, fish, etc., are all employed, either as prepared manures or mixed with earth, and applied as composts. These substances are largely used in the cultivation of hops.

Sulphate and Muriate of Ammonia and Sulpho-muriate of Ammonia.—These highly-nitrogenous manures are peculiarly adapted for grasses and cereals. They may be applied as spring-dressings, at from 1 to 2 cwt. per acre.

Nitrates of Potash and Soda.—The former is rarely used, on account of its high price; the latter is one of the most effective wheat manures we possess. It must be applied in the spring, as it is apt to waste through the soil when subjected to long-continued rains. It should be sown at the rate of from 1 to 2 cwt. per acre.

Common salt is supposed to increase the strength of straw in cereals, and it has a marked effect on mangel-wurzel growing on light soil. The effect of common salt is, however, exceedingly various, and sometimes injurious (Anderson). It may be used at the rate of 5 cwt. per acre.

Salts of Potash, Kainite.—Owing to the discovery of crude potash salts in Germany, potash is now offered at a cheap rate to farmers. Its value is not yet thoroughly appreciated, but it is likely to prove very valuable as a manure for potatoes, clover, and probably other leguminous plants.

Superphosphates, Dissolved Bones, Mineral Superphosphate.—These substances are more generally used than any of the other portable manures. It is by means of superphosphates that the swede and turnip crop is principally raised. These manures are also beneficially applied to grass-land, where they sweeten the herbage rather than increase its bulk. For cereals their use is somewhat doubtful, but they are used for this purpose in combination with nitrate of soda. 3 cwt. per acre is a fair dressing for turnips or swedes; sown with the seed, and either mixed with ashes (burnt soil) or water.

Inch and Half-inch Bones, Bone-dust.—The timid farmer, who fears to trust himself in the hands of the manufacturer, or who is unable to read a chemical analysis, prefers the genuine and visible bone to the impalpable superphosphate. Bones may be at once applied, or dissolved at home by means of sulphuric acid. They form an excellent turnip manure, and half a ton per acre applied to grass-land is a good permanent improvement.

Lime may be applied in the form of marl or chalk, or it may be calcined in a kiln, and distributed over the land as slaked lime. (See our second paper, page 171.)

OBJECT DRAWING.—V.

It will have been observed by the attentive student that the principles which govern object drawing are identical with those which have been explained already in our lessons in "Practical Perspective," and that much which is said in the present series of lessons has been already laid down in detail in that all-important subject, which may well be termed the "grammar of drawing." It must, however, be remembered that the aim of each series of lessons is different, and that in "Object Drawing" the pupil is taught to apply in delineating models and other subjects, truthfully and readily, but without rule and compass, the various rules and processes that he has worked out by the aid of instruments in our lessons in "Practical Perspective."

We now proceed to apply the principles which were laid down in the last lesson.

Fig. 31.—In this example it will be seen that *a b* is the edge of a cube which is nearest to the spectator, and this must therefore be drawn of its proper length.

Now from *a* and *b* draw lines to the horizontal line, which, in this case, is above the object. The vanishing-points will now be outside of the paper.

The cube is supposed to be placed at equal angles; but, as the eye is a little towards the right side of the object, the line *a d* will be longer than *a c*, and thus the right side of the model will be represented as it would actually appear—wider than the left.

Having completed the base of the cube *a c e d*, and raised the perpendiculars *c f* and *d g*, from *f* and *g* draw lines to the opposite vanishing-points, and their intersection will give the distant angle of the upper surface of the cube.

In this quadrilateral draw diagonals, and at their intersection raise a perpendicular. On this mark the height of the pyramid, which will be completed by drawing lines from the apex to the angles of the upper surface of the cube.

Fig. 32.—This is the slab already drawn in a previous lesson (Fig. 24), and will require but little explanation. It stands on edge, its sides being parallel to those of the cube (Fig. 31); and therefore the lines which are horizontal in the model will converge to the vanishing-points belonging to Fig. 31.

It must, of course, be borne in mind that whatever may be the inclination of these surfaces to the picture-plane, so long as the edges are horizontal—that is, *parallel* to the *ground*—their vanishing-points must be on the *horizontal line.*

The student must understand that when the term "horizontal" is used in relation to the *object*, it is meant in a different sense from "horizontal" in the drawing. Thus in Fig. 11 (page 132), the upper and lower edges of the front square of the cube are *horizontal* in the model, and are rendered horizontal in the drawing because the surface is parallel to the picture-plane; but the upper and lower edges of the right-hand side of the cube are horizontal also in the *model;* yet as they are at right angles to the picture-plane they are drawn to the point of sight. Again, the lines *a′ d*, *b′ c*, *b′ c*, and *a′ f* in the model (Fig. 32) under consideration, are all in *reality* horizontal lines; but being inclined to the picture-plane, they converge to the vanishing-points as already shown.

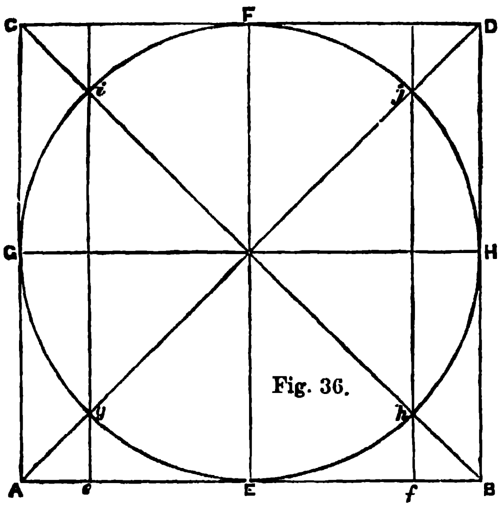


Fig. 36.

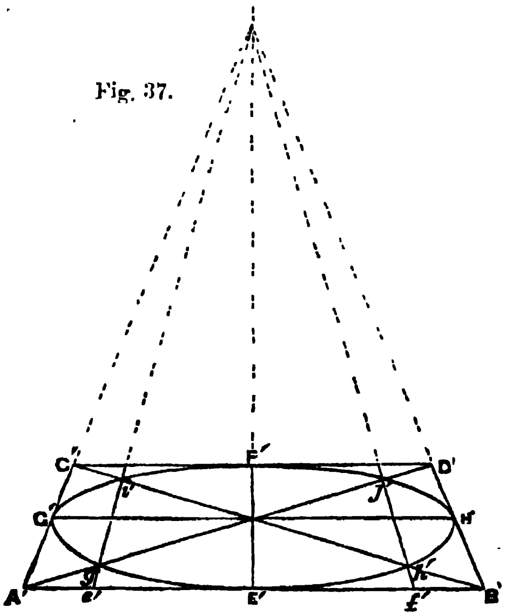


Fig. 37.

Fig. 33 is an equal-sided triangle or prism standing on its end, one of its rectangular faces being parallel to the plane of the picture.

Now it is evident, that if a sheet of glass were placed vertically so as to touch the perpendicular *a b* in Fig. 31, and $a'' b''$ in Fig. 33, the sides of the triangular prism would recede from it more suddenly than would those of the cube, because, as shown in Fig. 34, the angle between the face of the cube and the picture-plane would be 45°, whilst in the case of the triangular prism (Fig. 35) it would be 60°.

Therefore the vanishing-points for the triangle will be nearer to the perpendicular than they would be if the object to be represented were a cube. The width of the sides must depend on the position of the spectator; but however much the eye may be moved to the left or right, the points *c d* and *c f* must be on the same horizontal lines so long as the object is placed at equal angles.

The student is urged to remember that the present course of lessons is not by any means intended to supersede, or to be a substitute for, the study of perspective proper. Its object is (1) to give general elementary notions of solid forms to beginners, and by showing them the absolute necessity for really scientific knowledge, lead them on gradually to the more severe studies of projection and perspective; and (2) further, it is hoped, that to those who have already from our previous lessons acquired some knowledge of perspective as a science, the studies herein will afford opportunities for carrying out by the hand and eye alone the principles which they have previously worked out with the assistance of rule and compass, and will suggest to them the method of sketching the thousands of objects which they see around them.

Again and again it is earnestly impressed on all who would really derive from these lessons all the benefit intended, that they *must not merely copy the figures;* but that they should place the models, and draw directly from them; and further, when they have mastered the objects in the prescribed positions, they are advised to change their places and apply the principles which have been laid down.

We now proceed to speak of the method of drawing circles and cylindrical bodies, and must at the onset remark that perspective does not deal with circles or other curves as such, but requires that they should be enclosed in rectangular forms; those are then put into perspective, together with the points in them through which the curve passes. In the case of a circle, the nearest rectangular form which can enclose it is a square; and we will therefore show the method of drawing a circle by this means.

In Fig. 36 is a circle which we require to draw when lying horizontally below the eye of the spectator.

About the circle describe the square A B D C, and in it draw the diagonals A D, B C, and the diameters E F and G H. Now proceed to the sketch (Fig. 37). From A′ and B′ draw lines to the point of sight. Draw the line C′ D′, representing the back of the square. Draw the diagonals A′ D′ and B′ C′, and the diameters E′ F′, G′ H′.

Having proceeded thus far, return to the original figure, and draw the lines *e* and *f* through the points where the circle passes through the diagonals—viz., *g*, *i*, *h*, *j*.

Mark off on Fig. 37, from A′ and B′, the distance A *e* or B *f*—viz., A′ *e*′ and B′ *f*′; and from these points draw lines to the point of sight. These lines, passing through the diagonals, give the points *g*′, *i*′, *h*′, *j*′.

Eight points are thus obtained—viz., E′, *g*′, G′, *i*′, F′, *j*′, H′, and *h*′. Through these the curve which is the perspective representation is to be drawn.

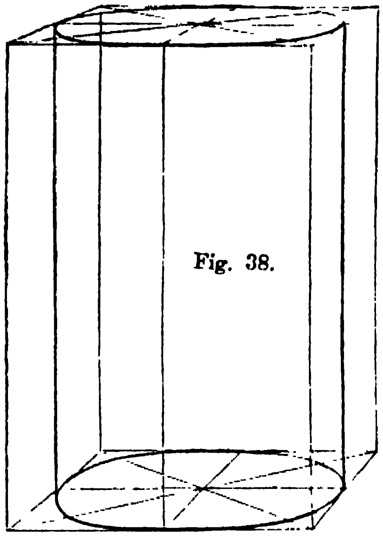


Fig. 38.

Now, as the *circle* just drawn is shown to be described in a plane *square*, it is clear that a *cylinder* would be contained in an oblong *block*, the ends of which are *squares*.

Proceed, therefore, to sketch such a block (Fig. 38), and, guided by the knowledge of the principles laid down in Figs. 36, 37, draw the elliptical figures representing the upper and lower ends.

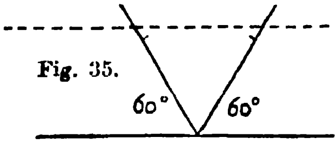


Fig. 35.

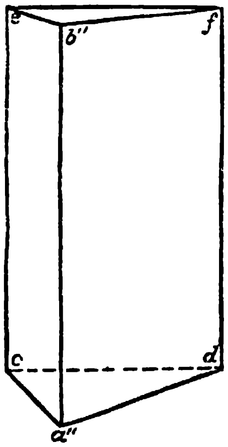


Fig. 33.

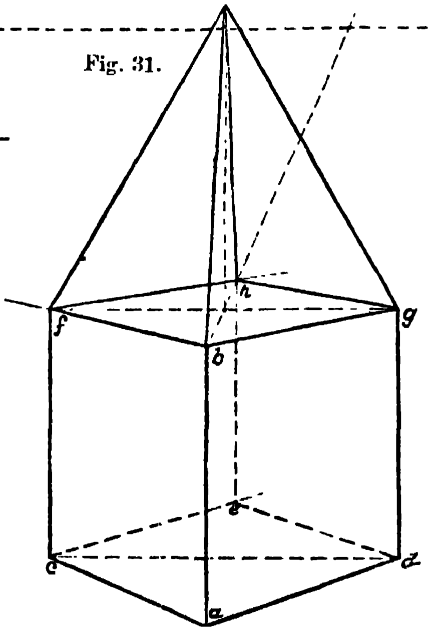


Fig. 31.

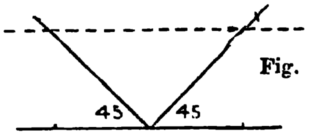


Fig. 34.

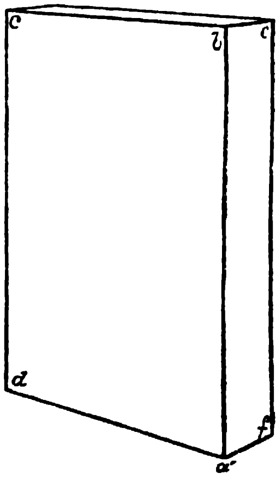


Fig. 32.

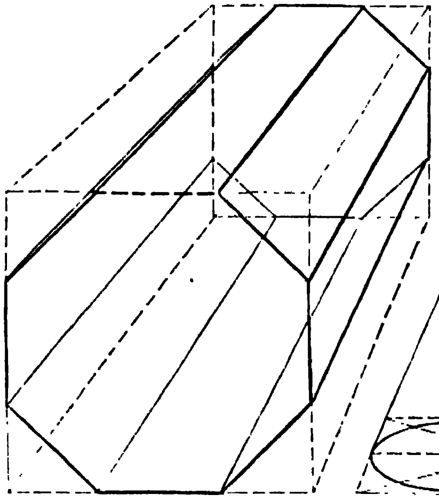
Great care must be taken in drawing the perpendiculars; they must join the curve in a smooth manner, so that no sharp point of junction is visible, and yet the object must not appear as if it were rounded off at the bottom, which gives a cylinder an unsafe or sack-like appearance, and makes it look as if it would not stand upright.

It is needless to say that a cylinder placed horizontally would be drawn in a similar method; the position of the oblong being changed according to that of the cylinder.

Fig. 39.—This is an octagonal prism. The end of the prism is parallel to the picture, and therefore retains its geometrical shape. Various methods for constructing polygons are given in lessons in "Practical Geometry applied to Linear Drawing," and it is assumed that the student has already acquired this knowledge; if not, he is urgently advised to commence the study at once, as it is the basis of all other useful drawing.

The figures in the present study are not, however, intended to be constructed geometrically, but the knowledge of the principles will materially aid in the rapid and correct delineation.

Fig. 39.



Having, then, drawn the octagonal end, draw lines from the angles to the point of sight; and it will be remembered that the distant end, since it is parallel to the near one, retains its regular shape so that no further instruction will be necessary to complete this object.

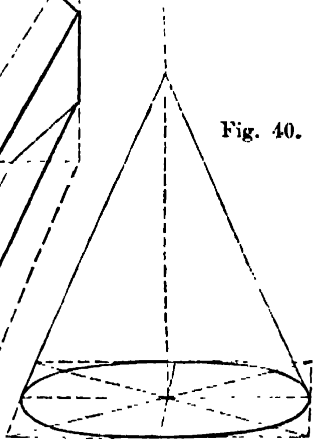


Fig. 40.

Fig. 40 is a perspective view of a cone. Having drawn the figure containing the base, draw diameters, diagonals, etc., and raise a perpendicular from the intersection.

Trace the curve in the quadrilateral, and draw the lines for the surface of the cone.

It is needless to say that these straight lines, enclosing curved forms, are only to be used as guides in the early stages of study; but a very little practice will soon enable the student to sketch the required form at once, using merely a horizontal for the diameter.

THE ELECTRIC TELEGRAPH.--XII.

By J. M. Wigner, B.A.

HOUSE'S PRINTING TELEGRAPH—HUGHES'S INSTRUMENT—INSTRUMENTS USED AT PRESENT TIME IN THIS COUNTRY—ARRANGEMENTS AT CENTRAL OFFICE—CONCLUSION.

The alphabetical or universal telegraph we have just described is admirably adapted for use on private lines, and has been extensively adopted. For ordinary telegraphic purposes, however, it is far inferior to the single-needle and Morse instruments, as a less degree of speed is attainable by it; and, at the same time, its more complicated construction renders it more expensive and liable to get out of repair. The electric current, too, is produced by induction from a permanent magnet, and is therefore too weak to be used on long lines.

Many attempts have been made to produce an instrument that should print its messages in ordinary printing characters, so that the strip itself as received might be sent out of the office without the labour and risk of transcribing. In Bonelli's printing telegraph, already described, this is accomplished; but, as we saw, five line-wires are required instead of one, and the instrument is thus rendered of little practical value. Several others have been devised to attain the same end with one wire. In most of these the letters of the alphabet and other signs are engraved round the edge of a steel type-wheel, which is made to revolve by clockwork, and the motion of which is controlled by means of a scape-wheel and an electro-magnet, somewhat in the same manner as in Breguet's instrument, described in our last paper.

This type-wheel revolves against an inked roller, and is made to stop when the letter to be printed is opposite the paper strip. The strip is then, by means of suitable mechanism, pressed against the inked type, and thus the letter is printed. As the strip recedes from the type, it is drawn forward a short distance, so as to be ready to receive the next letter. One blank space is left in the type-wheel, and this leaves a blank on the paper. By sending this an interval is left between the different words of the message.

An instrument of this kind, invented by a Mr. House, of New York, was extensively adopted on many American lines. The contact-wheel by which the currents were sent was divided into twenty-eight spaces, for the twenty-six letters, the full stop, and the +, which left a blank on the recording strip. Each alternate space was then cut away, so that it really became a wheel with fourteen teeth. A spring was pressed against these, so that the contact was alternately made and broken at each letter. On the axis of this wheel was placed a cylinder, with twenty-eight pegs fixed at equal distances in a spiral line round it.

The letters were engraved on the notes of a key-board, somewhat resembling that of an ordinary piano; and when any one was pressed down it raised a cam, which caught against the pin on the cylinder corresponding to its letter, and thus arrested its motion at the right moment. In the receiving instrument the paper was pressed against the type by a mechanical arrangement, and not by an electro-magnet, as is done in most similar instruments.

Hughes's printing telegraph is a very great improvement on this instrument, and is now in constant use on many important lines, both in England and abroad. It is the only instrument which prints its messages in ordinary type that is now employed by the Postal Telegraph Department in this country.

The principle on which it acts is to ensure the synchronous movement of an inked type-wheel at each station. In this there is, of course, great practical difficulty; but it has been fully overcome, and though the type-wheels make 120 revolutions a minute, they keep time with the greatest accuracy.

The regulator employed for attaining this uniformity of motion consists of a spiral vibrating spring, firmly fixed at one end. The type-wheels are set in motion by a heavy weight and a train of clockwork. A small fly-wheel driven by this is connected to the free end of the vibrating spring, so that the greater the motive power the greater will be the arc of vibration, but its rate will remain uniform. In order to adjust it accurately, a small sliding weight is placed on the spring, and this can easily be moved and clamped at any required place. This spring, therefore, acts in the same way as the pendulum in an ordinary clock, and is capable of as delicate adjustment.

Even with this, however, the type-wheel might be very slightly out of position, and thus would not print the letter clearly. A wheel with wedge-shaped teeth, known as a "corrector," is therefore mounted on the same axis as the type-wheel; and just before any letter is printed, a wedge-shaped cam strikes between the teeth of this, and forces it into its exact position. This correction takes place at every letter that is printed.

The construction of the whole apparatus is far too complicated to allow of the details being explained in the short space at our disposal, and almost any description would require an instrument by the side to render it perfectly clear. Its plan of working may, however, be easily understood.

The letters and signs are engraved on a key-board similar to that employed in House's instrument; two letters are, however, placed on each key, and there are two blanks. Either sign may then be sent at pleasure, according to which blank we depress. In this way fifty-four different characters, consisting of the letters, numerals, and various signs, are sent with twenty-eight keys. On the type-wheel the letters and figures are placed alternately, and by a suitable arrangement either can be printed at pleasure.

In the centre of the instrument is a horizontal brass disc, with a number of radial slots cut near the circumference. These correspond to the signs on the key-board, and as any key is depressed a pin connected to it by means of a lever is raised through the corresponding slot. Above this disc is a vertical shaft, revolving simultaneously with the type-wheel, and carrying a contact-making arm. As this revolves it comes in contact with any pin that is raised, and immediately causes a current to pass along the line-wire. This current sets free the printing-gear at each station, and thus causes the required letter to be printed. The keys corresponding to the successive letters of the message are then pressed down, and these are in like manner printed. In the type-wheel is a blank corresponding to one of the blank keys; this is sent at the end of each word, and leaves a space between it and the next. In this way the message is transmitted at a considerable speed, it being found that thirty or forty messages per hour may easily be sent by the instrument.

The electro-magnet which sets free the printing-gear is of peculiar construction. As the type-wheel revolves very rapidly, it is important that the paper should be brought into contact with it and again withdrawn as quickly as possible. A permanent horseshoe magnet is therefore employed, and has soft iron poles fitted to it, and wound round with fine wire. A spring on the armature tends to keep it away from the poles of the magnet. The tension of this is capable of adjustment by means of a screw, and it is so arranged that when the armature is against the poles the permanent magnetism is just sufficient to maintain it there despite the resistance of the spring. As soon, however, as the current travels round the coils, this permanent magnetism is reversed, and the keeper instantly flies away. In doing this it unlocks the printing-shaft, and allows the strip of paper to be rapidly pressed against the type-wheel and again withdrawn. By this latter movement the keeper is brought back again to the poles, and retained there till liberated by a fresh current.

The printing-gear is so arranged that at each letter printed the paper is drawn forward a short distance, so as to be ready to receive the next letter.

The strip of paper printed in this instrument is cut up, gummed to one of the ordinary message-forms, and sent out. No record is thus retained in the receiving-office, but this is not of much importance, as the message is printed simultaneously at the office from which it was sent, and the strip there is carefully preserved, should there be any need to refer to it afterwards. Before commencing work each morning a few blanks are sent, that is, the same key is pressed down several times in succession. If these print the same letter at each end, the vibrating springs are correctly adjusted; if not, they must be altered, and then all is ready to commence work. In order to start the type-wheels simultaneously, a catch is provided, and by pressing on this they can only start from the blank.

We have now hastily described all the chief forms of telegraph that have come at all into use, and it is hoped the student has acquired such a clear insight into their action that he will easily understand the principle of any other instrument he may met with. Only a few of these various instruments are, however, in actual work in this country at the present time; some others were for a time worked by different private companies, but have been discontinued since the various lines were taken over by the Government.

A short account of the instruments in use at the Central Telegraph Office in Moorgate Street, London, will give a good idea of the state of the telegraph system in England at the present time, and thus serve well to bring these papers to a close.

In this office there are several hundred instruments of various kinds constantly at work, the electricity required being generated in batteries which are placed in cellars beneath the building. The wires from these are led to the different instruments as required, under the various floors of the building.

One portion of the building is called the Metropolitan Gallery, and is set apart for messages to and from various parts of London; a separate division is used for provincial messages.

Desks or counters are placed across these rooms from side to side, and along these, at distances of a few feet, are placed the various instruments, nearly all of which are worked by young women. In front of each sits the clerk, with a supply of forms for writing the messages on placed in front of her; and over most of the instruments in the provincial gallery is placed a label showing the town with which they are in communication.

By far the greater number of instruments are the ordinary single-needle and the Morse recorder, which have already been described. Nearly all of the single-needle instruments are, however, now worked with a double tappet, similar to that described and figured in Vol. I., page 401, instead of with the barrel commutator previously described, this being now almost entirely confined to double-needle instruments.

The commutator is usually fixed in the same case as the coil, so that the two tappets or finger-plates project from it in place of the handle. The instruments made in this way are cheaper and less liable to get out of repair, though many of the clerks prefer the older form.

Morse instruments of every kind are also to be seen. In what might be called the standard form, the key, recorder, and galvanometer are placed on the same stand; but there is a very great diversity in the form given to the different instruments. All, however, act in the same way, as has been fully explained.

A few of Wheatstone's automatic instruments, somewhat modified, may also be seen in one of the rooms. In these the paper strip is punched in a somewhat different way from that already described, the object of the alteration being to allow the ordinary Morse recorder to be used either with the key or the punched strip. The punching apparatus is so arranged that at each blow on the anvil two holes are punched, one at each edge of the strip. When a dot is to be sent, these holes are placed directly under one another, thus $\overset{\circ}{\circ}$, while a dash is denoted by two placed in this manner, $^{\circ}{}_{\circ}$; and the transmitting apparatus is so arranged that these cause one current of longer duration to be sent, and so print a dash at the receiving station. A middle row of holes is punched along the paper at the same time to space the words. The word "Morse," as punched in this way, is here shown (Fig. 56), the equivalent dots and dashes being placed under the various characters.

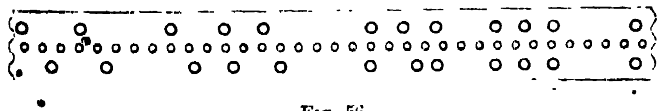


Fig. 56

In the same room is one desk at which a number of the Hughes' printing telegraph just described may be seen at work, and these constitute one of the most interesting features of the

In addition to these instruments, there are a few of the American "sounders," which have been introduced very recently, and one or two specimens of Bright's bell instrument. Speaking roughly, however, we may safely say that the two instruments employed are the single-needle and the Morse.

Between large and important towns through wires are usually provided, so that messages are sent direct from one to the other; but in a large number of cases the message has to be received at one instrument and re-transmitted along another line. The wires might be put in direct communication by means of switches, but in practice it is found far more rapid to receive and re-transmit the message. Sometimes a message has thus to be telegraphed several times before reaching its destination.

To save the great trouble and loss of time which would be caused by carrying these messages from one part to another of the building, a series of endless tapes has just been fitted in the office. These pass round rollers kept in constant motion, and the message, being placed between them, is at once conveyed from the Metropolitan to the Provincial Gallery, or *vice versa*.

Between some City stations, and between this office and the General Post Office, there are so many messages constantly passing that several wires would be required. Pneumatic tubes have therefore been laid down, and the message, written in the ordinary form, is rolled up, inserted in a carrier made to fit these, and propelled along them to the required station, where it falls out of the tube on to a tray placed to receive it. A vacuum is produced in these tubes by steam-power, and the carrier is sucked one way and propelled the other.

A larger tube has now been laid down between Moorgate Street and the office in the West Strand, calling at Temple Bar on the way, and many messages are constantly being transmitted along this. The plan seems, indeed, to answer so well that it will probably be extended to other important stations.

We have thus completed our survey of the English telegraph system, and have seen some of the results that have accrued from the simple discovery made by Galvani.

Had any one ventured half a century ago to predict that our messages would be flashed at lightning speed to distant continents, and answers received in the space of a few minutes, he would have been deemed mad; but even this has now been far exceeded. In scarcely any other branch of science has such rapid progress been made, and we are still hearing of fresh discoveries; though there has been but little change in the instruments employed during the last few years.

COLOUR.—XII.

By Professor CHURCH, Royal Agricultural College, Cirencester.

COLOURED GLASS—COLOURS OF POTTERY AND PORCELAIN—MINERAL PIGMENTS—COLOURS OF PLANTS, FLOWERS, WOODS, AND VEGETABLE FIBRES—COLOURS OF ANIMALS AND ANIMAL PRODUCTS.

WE have now to consider the peculiarities of coloured glass. Glass, being a vitreous and not a crystallised substance, does not present that extensive variety of optical properties which characterises many natural gems. It is probably on this account that the most perfect and uniform coloured glass is not by any means satisfactory or interesting from an artistic point of view. Very instructive examples of the bad effect of such glass are to be seen in many painted glass windows, especially in those which belong to the earlier period of the recent revival of Gothic art in this country. The blue and other glass is deep enough in colour, but lacks real richness; it is thin and flat, though staring. There is no fluctuation of colour, no breaking up and scattering of the transmitted beams of light. The glass to accomplish this must be less perfect as a mechanical product of manufacture. If the colour be uniformly diffused throughout the glass, the glass must vary in thickness, its surfaces must be uneven; and striæ and blobs only improve the effect. A glass which is absolutely perfect as glass may be rightly devoted to the construction of optical instruments, but is incapable of completely realising the poetry of colour.

The colours of glass may arise from several causes. A fine white powder—say oxide of tin—diffused through clear glass gives it the opalescence of a cloudy medium; a bluish colour being produced by reflected light, and a yellow or red colour by transmitted light. Opal glass may vary from a faint cloudiness to milky and nearly opaque white. Another glass, owing its peculiarity to solid matter, is known as aventurine glass; it contains glistening crystals of copper. But the colours of most transparent glasses are due to the presence of metallic silicates, such as those of iron, copper, cobalt, and manganese. These metals give to glass various tints of green, orange, blue, and violet. One metal, uranium, imparts not only a distinct yellow colour, but the interesting property called fluorescence. The common "canary" glass is a glass of this kind. Viewed by transmitted light it is yellow; but when the solar beams fall upon this kind of glass, the actinic rays are modified, and are reflected back to the eye as green light.

The method of using coloured glass in windows should be limited very strictly by the nature of the material, as well as by the office of a window. The glass must not pretend to be a picture, nor must it contain large shaded or obscured portions, opaque or nearly so to light. Minute lines and details of drawing are out of place and useless. A mosaic work of small pieces of glass, separated by bold and firm lead lines, is most effective. If the window is required to let in unmodified daylight, the glass may be decorated with firmly-drawn outlines in dark maroon or brown upon a white or grey ground, the pattern extending through a large number of quarries. Here and there a medallion of richer colour may be symmetrically introduced. Where highly-coloured windows are considered desirable, some of the richest and happiest effects are to be obtained by the use of blue glass in preponderating quantity, as in the ancient glass of Canterbury Cathedral, or of ruby-red with blue, as in the windows of La Sainte Chapelle, at Paris. Some portions of the latter glass may be studied at South Kensington. Where the pieces of glass are small, the effect of the contiguous beams of red and blue light is to produce a result similar to that of violet glass, but infinitely richer, more brilliant, and more "bloomy;" while the lead lines prevent a confused mingling of the colours when seen more closely. Mosaic work in coloured glass is most appropriate and effective. Painting in *chiaro-oscuro*, especially in monochrome, is radically bad in theory, and unpleasant, to say the least, in result.

The peculiarity of the colours of porcelain and pottery consists mainly in the mode in which they are applied to the wares. In the case of delft, faience, and majolica ware, the colours are painted, as enamel colours, upon an opaque white or nearly white stanniferous enamel. Transparent or translucent colours on this opaque ground come out with great force; while opaque colours appear less characteristic than they do upon porcelain, and upon translucent bodies generally. Upon earthenware and porcelain, designs may be either printed or painted, either under or over the glaze. Colours printed or painted over the glaze are generally better defined and more brilliant than those which are below it. In the decoration of pottery and porcelain, besides the use of enamel colours, other decorative effects may be produced by means of preparations of gold and platinum, and by means of colours mixed with the body of the ware or the glaze. Some of the most remarkable effects of the latter sort are to be seen upon the old Italian lustre-ware plates, and upon the modern porcelain of M. Brianchon, imitated at Worcester and Belleek, in which cases the iridescent glaze contains a considerable amount of bismuth in its composition.

A very important series of coloured materials is produced directly or indirectly from minerals. Most of the native mineral pigments are of a useful and permanent character. The compounds of iron, chiefly oxides and hydrates, have always been largely employed in the arts, and afford a wide range of useful colours—yellows, reds, browns, maroons, etc. The colours derived from copper, such as verdigris and malachite, are more liable to change by conversion into the black oxide and dark brown sulphide of this metal. Pigments made out of coloured glass or frit—such pigments, for instance, as smalt and ultramarine—are commonly difficult to manipulate and mix, but yet are endowed with considerable fixity. Preparations of lead, such as the carbonate and the chromate, white lead, and chrome yellow respectively, are subject to one great drawback. This is their sensitiveness to sulphuretted hydrogen, which darkens and destroys all the more delicately-coloured preparations containing this metal with considerable rapidity. The protection of these materials from change is partially effected by covering the particles of which they consist by a film of oil-varnish, wax, paraffin, or gum, as in the ordinary methods of painting in oil, encaustic, or water. In fresco and distemper painting, where lime or size serve to bind or cover the pigmentary granules, the action of injurious substances upon sensitive materials is more rapid. In stereochromy, and other methods of silicious painting, the colours are less liable to change. But then the range of colours is rather limited, owing to another consideration—water, glass, and the alkaline silicates in general, which constitute the médium with which the pigments are mixed in stereochromy, or with which they are fixed, alter and destroy many mineral colours, such as emerald green, Prussian blue, and chrome yellow. If we exclude such alterable pigments, including most preparations of lead and copper, and then further eliminate, for the same reason, some of the most beautiful vegetable and animal colouring matters, the residue of available pigments is indeed small. The point, however, to which we now wish to draw attention is not the modification of colour by injurious atmospheric or other influences, but the colour-peculiarities caused by the nature of the medium with which the pigments are incorporated, or by the optical qualities of the pigment itself. The most important general characters of pigments reside in their translucency, or opacity, as regards light. A transparent pigment need be much less saturated or intense to produce a given colour-effect than an opaque one. The reason of this will be clear when the statements made in former lessons are recalled. The light reflected from the ground on which a transparent colour is laid has to pass *twice* through that colour; while an opaque colour often reflects, or at least scatters, much unaltered white light. The use of clear colours upon opaque grounds or painted surfaces is often called glazing by artists, and gives a depth, intensity, and richness which cannot be exactly attained in other ways. *Scumbling* is the precise opposite of this, for in it an opaque colour or white, mixed with some oil or other medium, is used to cover partially, and so to modify, the clear or mixed colours which have been previously laid on. It conveys an idea of distance, or mystery, or cloudiness.

The binding material which unites the particles of a pigment together, or which retains them on the painted surface, may be either opaque or transparent. In all ordinary water-colour and oil-colour painting, the binding material is practically transparent; but in fresco painting it would seem that the freshly-covered surface acquires a film of carbonate of lime (calcium carbonate), which gives deadness and opacity to the surface of pictures executed by this method. Something of the same kind of effect is produced in the several methods of silicious painting, of which the only one which is of any importance, and has been practically employed, is the stereochromy of Fuchs In this process the pigments are bound to the wall, and acquire coherence by the changes which the soluble potassium and sodium silicates used in the process undergo. They appear to enter into direct combination with the zinc oxide or calcium carbonate laid on as a ground or mixed with the pigment. The silicate must not be saturated with silica, but should be, contrary to the usual opinion, strongly alkaline; otherwise an irremovable silicious bloom will shortly disfigure the mural painting executed by this process. The wall, slate, plaster, or stone to be decorated should be wetted with baryta-water, painted with the previously-tested colours, and then, when dry, syringed with a fine spray of the fixing silicious solution. This syringing is repeated at short intervals, until no trace of colour can be removed with a dry or wet hard brush applied to the painting. If a saline bloom appear after a time, it should be removed by means of sponging with distilled water. If a hard white silicious bloom mar the brilliancy of the colours, no chemical or mechanical method is competent to remove it. But in this case the appearance of the injured fresco or stereochrome picture may be greatly improved by a process which the writer of these lessons invented in 1856. It consists in the use of paraffin, driven into the picture by heat, or applied in the form of solution, by a brush or in spray. The solvent used may be either benzole or mineral turpentine. Some fine copal or dammar varnish is a desirable addition to the solution. In this way old distemper paintings may be preserved from destruction. The effects of damp and decay are arrested, and the colours may actually acquire more than their pristine beauty. In fact, this process converts the opaque binding materials of the painting into transparent or translucent ones. It is scarcely necessary to say that all colours, oils, and varnishes should be tested before they are used, if their colours and appearances are to remain unchanged. No soluble saline matters should remain in pigments; they ought to be tried alone and mixed with others, to see if they alter or fade when exposed to sunlight. The oils and varnishes must be examined to see whether they darken, or if they irregularly contract on drying, and so forth. But we must not dwell further on the chemistry of pigments, of grounds, and of the media and methods of painting, for this subject requires a volume for its adequate treatment. Yet we must add a word or two on a subject of the utmost importance to artists, and to those who are engaged in copying pictures. As the colours which we see are modified subjectively, it is necessary that they should not be reproduced as we see them, but as they actually exist. The high lights of a blue robe may appear yellow or orange to us, and yet could be copied only by the use of a lighter tone of blue. So the high lights of a face may give by way of contrast a greenish hue to its shaded parts, although this effect would not be reproduced, but grossly exaggerated, by mixing some green with the grey of those parts.

The most conspicuous colours belonging to flowers are usually very fleeting, and cannot be utilised for decorative purposes. Generally, too, they are particularly liable to alteration by acids or alkalies—becoming red under the influence of the former agents, and blue or green by the action of the latter. This property has been turned to account in chemical testing; one of the best test-papers being prepared from that beautiful crimson-foliaged plant, the *Coleus Vershaffeltii*. The stems of the plant are bruised and extracted with spirit; then white blotting-paper is soaked in the solution. The lavender-grey of this paper becomes red with acids, and green with soda and other alkalies. In the copper-beech and the dark portions of some zonal geraniums, we have the ordinary green colouring matter of leaves, called chlorophyll, mixed with a crimson colouring matter, the combination producing a kind of deep maroon. The extreme beauty of the colours of many flowers depends in part upon their peculiarities of structure. The cell-walls within which the vegetable pigments occur are often extremely thin, and present a soft yet glistening aspect, which enhances and varies the colour-effects of their contents. This aspect, though often called crystalline, in no degree arises from any structure to which this term can be applied. Some very beautiful and yet permanent colouring matters are, however, obtained from plants, though these do not always contain them ready-formed. As instances in point, we may cite indigo and some of the madder colours.

The vegetable fibrous materials used in the manufacture of textile fabrics are generally white or pale yellow, but may be dyed of any colour by suitable processes. In some cases the dyeing material may be made to enter a central cavity in the fibre; but usually colouring substances can be made to adhere permanently to vegetable fibres only by means of a mordant. First of all, a substance such as tin peroxide, having an attraction for colouring matter, is precipitated upon the fibre, and then it is immersed in a dye-bath. The colouring matter is withdrawn from the liquid, and adheres firmly to the mordanted fibre. The lustre of vegetable fibres is usually not very marked, and is diminished in the process of dyeing them. Linen, the woven fibres of flax, does, however, reflect the light which falls upon it with considerable power, particularly in certain positions. A pattern may thus be made in which the strands which form the warp may be contrasted, not only as regards colour, but as regards lustre, with those of the woof. Under these conditions damasked linen, just like silk damask, may exhibit a curious optical illusion. If a white warp and a red woof be associated, it will be noticed that in certain lights the white parts of the fabric assume a bluish-green tint, acquiring, very distinctly, the tint complementary to the dyed threads, the effect being enhanced by the difference of lustre dependent upon the way in which the light falls upon the fabric. Similar but still more decided effects are seen in fabrics in which lustrous silk and dull cotton or wool are associated. Nor should we here neglect to allude to the peculiar mingled tones produced by the repeated recurrence at short intervals of similarly coloured strands in a fabric.

The colours of woods are usually subdued, but varied. Much of the beauty of some woods depends, however, rather upon texture and lustre than upon colour. In furniture, and the general decorative treatment of wooden construction, much may be made out of the combined use of these two qualities of lustre and colour. One wood dark, and of lustrous texture, may be introduced in the form of bosses, panels, or mouldings into a framework of an opaque and light wood. So woods of distinct patterns may be associated with those which possess an uniform appearance. The colours of woods are, indeed, brought out by varnishing and oiling; but the former of these processes has a tendency to check those alterations of tint which often render old specimens of woodwork far more beautiful than new.

The colours of animal products are usually less changeable than those of vegetable products. In some cases, notably in the case of the humming-birds, the brilliant, almost metallic, colours of the animals are due rather to the optical structure of the coloured substance and surface than to any actual colouring matter. Instances, however, do occur, as in the plaintain-eaters, or touracous of Africa, where a colouring matter may be actually extracted from the brilliant plumage of birds. The colouring matter of these birds was discovered by the present writer, and found to resemble the red colouring matter of arterial blood (*cruorin*) in some respects. It is especially remarkable as containing a fixed per-centage of the metal copper. White feathers, like other animal products, may be dyed without any mordant, silk and wool being particularly characteristic examples of this fact; ivory, bone, and horn may be noticed in the same connection.

If our treatment of the subject of colour has sometimes seemed to our readers to have been destitute of practical value, we yet trust that the principles laid down will serve to furnish a guide, at once effective and safe, in the arrangement and study of coloured compositions, both pictorial and decorative. Further information may be gained, both as to textile fabrics and paintings, from "The Laws of the Contrast of Colour," by M. Chevreul; while Dr. E. Brücke's treatise on "Colours," which may be read in the French translation of Dr. Schutzenberger, enters more fully into the physical and physiological matters connected with this subject. Besides the papers of the late Dr. George Wilson, of Helmholtz, and of Professor Clerk Maxwell, we have two excellent works from the pen of Mr. W. Benson. These latter are entitled respectively, the "Principles of the Science of Colour," and a "Manual of Colour," and deserve careful study. Nearly all these works contain something about the singular condition, to which we have been able to allude but cursorily, known as Daltonism, or colour-blindness. A nomenclature of colours, unfortunately imperfect, will be found in Brooke and Miller's "Manual of Mineralogy;" but it is greatly to be desired that the names used to indicate the most important varieties of colour should be applied in a more definite manner.

SANITARY ENGINEERING.—V.

SUNBURNERS.

In some previous papers, having for their subject "Gas" in its various phases of use—as a manufacture, as an economical means of lighting, etc.—we have given technical details bearing upon different aspects of the subject. The question before us—the use of sunburners—has special reference to the lighting of large public buildings, theatres, churches, manufactories, or any large room, where the cost of the light is not so much an object as that there should be a good diffused general light, and plenty of it, and that this result should be obtained without interfering with the ventilation, or, in other words, that the products of combustion, the carbonic acid gas and other fumes which produce the closeness in all large gas-lighted spaces of which we now so constantly complain, should be efficiently removed; and this result is surely and efficiently attained by the adoption of the "sunburner."

In some of our previous papers economy in consumption has been the point in view. In this case that has to a certain extent to be disregarded, a thoroughly good light, combined with efficient ventilation, being the object sought after in all public undertakings, the mere cost of gas burnt being a somewhat secondary consideration under the circumstances.

The burner consists of a number or group of union jet burners, commonly called fish-tails, arranged in the form of a circle or a star, larger or smaller according to circumstances, but so placed as to throw out their flame horizontally and not vertically, the draught of air being regulated accordingly. These were originally, on the first introduction of this method of lighting, placed under a funnel made of sheet iron with a short pipe rising from it, which was encased by a larger funnel, from which a pipe, acting as the flue of the sunburner, was taken by the most convenient route to a communication with the external air.

When first used these funnels, being made throughout of iron, threw up on to the ceiling a very dense shadow, which, when it was necessary to fix the sunburner, as is sometimes the case, at some distance below, interfered very much with the architectural decorative effect of the room. This difficulty has been overcome by perforating these casings throughout their surface with a series of openings, and filling the openings thus made with sheets of mica, thus allowing the light to be distributed while confining the air. The great heat always generated by the light produces a strong up draught, not only removing the products of combustion, but creating in the space between the inner and outer shaft a current which keeps up a constant drain upon the heated air in the upper portion of the room.

In the earlier stages of the invention it was found, however, that when the gas was not lighted a strong down draught of cold air constantly passed down the pipe. A valve was then provided in the inner tube to control the draught, which, in the first instance, was moved by hand—opened at night when the gas was lighted, and shut when it was turned off. There was, however, this risk, which was a serious one: if by any accident the valve was left shut after the gas was turned on, the portion of air below it gradually became mixed with gas, until the mixture acquired that character well known as a highly explosive compound, and from which all the gas explosions of which we are constantly hearing arise.

Finally, a self-acting valve was invented, acting by the pressure of the gas in the supply-tubes on inverted vessels floating in mercury. When the gas is turned on this opens the valve, and when turned off it shuts it. All risk of explosion is thus avoided, and down draught effectually cut off. For obtaining a large body of fixed light in any given situation the sunburner, with these improvements, is undoubtedly one of the best, if not the best, means at our command.

In introducing the sunburner, however, the risk of fire has always to be provided against, as the heat generated is so great. In London the Building Act requires a space of nine inches between the flue and any combustible material; but this is more than is absolutely requisite, as half that space is sufficient for safety; and in the North it is not uncommon to have three or more wrought-iron tubes enclosing each other, each with air-space between, this forming a perfectly efficient protection.

The fittings of the burners should be adapted to the architectural character of the interior where they are used, and this is a point that has been carefully studied by different manufacturers, so that either a classical, or Gothic, or other character has been given to the decorations required either around the rim of the funnel surmounting the burners, or over the general surface of the tubes where visible. There are also many artistic designs for the adaptation of glass lustres to sunburners, which may thus be rendered equal in effect to the most elegant chandeliers or pendants, suitable either for the drawing-room, the ball-room, or the theatre. For ordinary household purposes—*i.e.*, for small rooms anything less than twelve feet high—we do not recommend the introduction of this method of lighting, as the great heat generated in the flues, which have to be conducted through the narrow space between floor and ceiling, has a marked effect both upon the timbers of the floor and the atmosphere of the room above, and the light required can be more economically and efficiently attained by a different arrangement of the burners; but for large public buildings where an audience has to be accommodated, or in large reception-rooms which have the necessary elevation, good light combined with efficient ventilation can be more readily obtained by this adaptation of gas-lighting than by any other.

For billiard-rooms, where sectional height permits its introduction, it has been found successful, and we may mention one or two public buildings where it has been adopted satisfactorily in the course of the last few months. The Gaiety Theatre is one of them, the well-known public room at Evans's another; here are a series of sunburners architecturally arranged so as to form centres in the various panels of the ceiling, which is highly decorated with gilding, colour, and figure-painting. Again, in the "shop," as it is professionally termed, of the Bank of England, at the corner of Threadneedle Street, a series of pendentives are arranged; the ceiling is groined, circular, and of high architectural pretensions; and the termination of each pendentive forms a very fitting position for the introduction of the sunburner, which is fixed at that point.

When provision is made in the erection of a new building for the introduction of this method of lighting, the cost will scarcely exceed that required for any other method, as the requisite fittings need not be more expensive than those ordinarily in use for other arrangements for lighting; and by a well-considered arrangement of flues the up draught of the sunburner may be made, in its general action, to assist the ordinary ventilating flues.

When a building already erected has to be thus lighted, of course care is required in the detail of construction to avoid risk of fire; but that once duly provided for we may safely say that for large rooms for public purposes the sunburner is the most efficient appliance of the day.

NOTABLE INVENTIONS AND INVENTORS.

XVII.—THE DIVING-BELL.

BY JOHN TIMBS.

THE contrivance of apparatus for enabling men to dive, or descend beneath the surface of water, to a greater depth, for a longer space of time, and with less exertion and danger, than is possible by the unassisted power of the body, long exercised the ingenuity of mankind in past ages. About half a minute is the longest period during which most individuals can safely remain under water—in fact, can *live under water*—without some provision for the supply of air for respiration. Experienced divers have never, with few exceptions, remained under water more than two minutes; and although exaggerated statements are given of divers remaining for hours under water, six minutes is about the longest time of submersion of which any trustworthy account has appeared in modern times.

The sponge-divers in the Archipelago take down in their mouths a piece of sponge soaked in oil, as a means for assisting the diver to see when under water. In still water, light is frequently transmitted to a great depth; but when the surface is disturbed by waves, it is much obstructed. To ensure a good light, which may enable the diver to find objects of his search without delay, it is stated that he ejects a little oil from the sponge, and this oil rising to the surface, and spreading upon it, calms the waves in a most remarkable manner, and occasions a brilliant light at the bottom.

Among the earliest plans is that mentioned by Aristotle, who is supposed to intimate that in his time divers used a kind of kettle to enable them to continue longer under water; but Beckmann places little reliance upon this statement. He adds, that the oldest information we have of the use of the diving-bell in Europe is that of John Taisner, quoted by Schott, in his "Technica Curiosa," Nuremberg, 1664, in which Taisner relates: "Were the ignorant vulgar told that one could descend to the bottom of the Rhine, in the midst of the water, without wetting one's clothes, or any part of one's body, and even carry a lighted candle to the bottom of the water, they would consider it altogether as ridiculous as impossible. This, however, I saw done at Toledo, in Spain, in the year 1538, before the Emperor Charles V., and almost ten thousand spectators. The experiment was made by two Greeks, who, taking a very large kettle suspended by ropes with the mouth downwards, fixed beams and planks in the middle of its concavity, upon which they placed themselves, together with a candle. The kettle was equipoised by lead fixed round its mouth, so that, when let down towards the water, no part of its circumference should touch the water sooner than another, else the water might easily have overcome the air included in it, and have converted it into moist vapour; but if the vessel were gently drawn up, the men continue dry, and the candle is found burning." Schott calls the machine described an "aquatic kettle;" but he also describes an apparatus called "aquatic armour," which would enable those who were covered with it to walk under water. This apparatus is engraved in Schott's work, and shows a man walking into the water, with a covering, like a small diving-bell, over his head, descending nearly to his feet.

In England a diving-machine was foreshadowed by Roger Bacon; and his great namesake, Francis Bacon, describes it as a reservoir of air, to which labourers upon wrecks might resort whenever they required to take breath. He thus describes it:—"A hollow vessel was made of metal, which was let down equally to the surface of the water, and thus carried with it to the bottom of the sea the whole air it contained. It stood upon three feet, like a tripod, which were in length something less than the height of a man; so that the diver, when he was no longer able to contain his breath, could put his head into the vessel, and, having breathed, return again to his work."—*Novum Organum*, lib. ii.

The bell was next used in America, in 1642, by one Edward Bedall, of Boston, to weigh the ship *Mary Rose*, which had sunk in the preceding year. Bedall employed two tubs, "upon which were hanged so many weights (600 pounds) as would sink them to the ground." The trial succeeded, and the guns, ballast, goods, hull, etc., were all transported into shoal water, and recovered. Next, the postscript to a volume by Professor Sinclair, Edinburgh, 1688, describes "how to buoy up a ship of any burden from the ground of the sea," and states that the late Marquis of Argyle, "having obtained a patent from the King, of one of the Spanish Armada, which was sunk in the Isle of Mull, A.D. 1588, employed James Colquhoun, of Glasgow, a man of singular knowledge and skill in all mechanical arts and sciences." "This man," he proceeds, "not knowing the diving-bells, went down several times, the air from above being communicated to his lungs by a long pipe of leather. He only viewed and surveyed the ship, but I suppose buoyed nothing up. Subsequently, the (then) late Lord Argyle employed the ingenious laird Melgin, who went down with a diving-bell, and got up three guns. A third and more successful trial was made; and a fourth by Captain Smith, who was so confident of recovering the gold supposed to be lost with the ship, that he would not admit a co-partner in the enterprise, which, however, came to nothing."

Among the oldest of representations of diving apparatus, Beckmann mentions a print in "Vegetius on War," 1511 and 1532, representing a diver with a cap, from which rises a long leathern pipe, terminating in an opening, which floats upon the water; also, a figure from "Lorini on Fortification," 1607, nearly resembling the modern diving-bell, and consisting of a square box bound with iron, furnished with windows, and used for the diver. In 1617, Kepton's "water armour" proved useless. In 1671, Witsen excelled in the construction of the diving-bell, which he erroneously states was invented at Amsterdam. In 1679, Borelli, the Neapolitan physician, is stated to have invented an apparatus by which persons might go a considerable depth under water, remain there, move from place to place, and sink or rise at pleasure; also a boat, in which two or more persons might row themselves under water; but the practical worth of these machines is much doubted.

The next claimant upon our list is William Phips, born at Pemaquid, in 1650. When of age, he built a ship at Sheepscote; he afterwards followed the sea, and subsequently became Governor of New England. He attempted to raise treasure from the wreck of a Spanish ship, sunk on the coast of Hispaniola—with what apparatus we are uninformed. His earliest experiment failed; but he prosecuted his scheme, and at length obtained the patronage of the Duke of Albemarle, son of the celebrated Monk; and in 1687, after many difficulties, he succeeded in raising a large quantity of treasure, with which he returned to England, where he was knighted for his enterprise. Most accounts state that the property he recovered amounted to £200,000; but in the "Life of Sir William Phips," published anonymously in 1697, and attributed to Increase Mather, it is stated at £300,000. There is a popular American opinion, that the Mulgrave family, of which the present head is the Marquess of Normandy, was descended from the above Sir William Phips, which is a mistake; the founder of the Mulgrave family being Constantine John Phipps, Commander of the unsuccessful Arctic expedition in 1773, who was raised to the British Peerage as Baron Mulgrave, of Mulgrave, County York, in 1790.

The next improver of the diving-bell was Dr. Edmund Halley, who in the "Philosophical Transactions" described the defects of the bell, and suggested a remedy for them. This paper alone would be sufficient, although it does not enter into the early history of the machine, to contradict the erroneous statement which has been made, that Halley was the inventor of the diving-bell.

The diving-bell, in its simplest form, is a strong heavy vessel of wood or metal, made perfectly air and water tight at the top and sides, but open at the bottom. If such a vessel be gradually lowered into the water, in a perfectly horizontal position, the air which it contains cannot escape, and therefore the vessel cannot become full of water. This may be readily illustrated by plunging a glass tumbler in an inverted position into a vessel of water, and placing a piece of cork, or any other substance that will float on the surface of the water, under the tumbler. If a bit of burning matter be laid upon the cork-float, it will continue burning, although the glass and all that it contains be plunged far beneath the water; thereby proving that the upper part of the cavity of the glass is occupied by air, and not by water. Still, the water fills a small part of the cavity of the glass, and rises more into it when it is plunged to a considerable depth than when the rim is only just immersed beneath the surface. This is caused by the condensation of the air contained in the glass, which, being very elastic, is condensed into a smaller space by the pressure of the superincumbent water, when the glass is plunged to a considerable depth, than it will occupy under the ordinary pressure of the atmosphere. When the diving-bell is used for descending to a very small depth, as the pressure of the water is small, it will not rise in the bell sufficiently high to be inconvenient; but at the depth of thirty-three feet, the pressure is so great as to compress the air into one-half of its original volume, so that the bell will become half full of water. At a greater depth it will rise proportionally higher in the bell, but it does not materially interfere with respiration, provided the descent of the bell be very gradual, as the air then balances the pressure from without. The principal effect of the increased pressure is felt in the ear, for when the condensed air has found its way into the cavities of the ear, the sensation then experienced is compared to that of having quills forced into the ears, or as if the ears were bursting. This continues until the pressure of the air on each side of the tympanum is balanced. But while the mere condensation of the air in the bell does not render it unfit for respiration, it would soon become so if no means were provided for renewing it from time to time, as it becomes vitiated by repeated respiration. Dr. Halley provided a remedy for this inconvenience, and for that of the contracted space left free from water, when, by being at a great depth, the air is compressed into a small volume, by a means of supplying the bell with any required quantity of fresh air without raising it to the surface.

The bell used by Dr. Halley was of wood, in the form of a truncated cone, the top diameter three feet, and the bottom five, and containing about sixty cubic feet. This he coated with lead, and so weighted it about the lower part that it would sink while empty, and would always remain in its proper position; that is, with the larger open end downwards, and its rim parallel with the horizon. In the top of the bell was a very strong glass window, and a cock to let out the foul air. About a yard below the mouth was suspended a stage, so weighted that it might hang steadily. The whole apparatus was suspended from a sprit attached to the mast of a ship, and provided with tackle, by which the bell might be raised or lowered; and the sprit might be slung round, so as either to carry the bell over the hull of the vessel, or to suspend it clear of her side. Air was supplied to the bell when under water, by two thirty-six gallon barrels, weighted with lead, to make them sink readily; each having an open bung-hole in the lower end, to let in the water, as the air in them condensed on their descent. There was also a hole in the upper end of each barrel, to which was fitted an air-tight leathern hose, long enough to fall below the bottom of the barrel, and so weighted that it would fall naturally in that position. These air-barrels were attached to tackle, by which, with the labour of two men, they might be made to rise and fall alternately, like the buckets in a well; and by lines attached to the lower edge of the bell, they were so guided in their descent that the mouth of the hose always came directly to the hand of a man who stood upon a stage suspended from it. As the apertures of the hose were, during their descent, always below the level of the barrels, no air could escape from them; but when they were turned up by the attendant, so as to be above the level of the water in the barrels, the air rushed out with great force into the bell, the barrels becoming at the same time full of water. By sending down these barrels in rapid succession, the air in the barrel was kept in so pure a state that five persons remained in the bell, at a depth of nine or ten fathoms, for more than an hour and a half at a time, without injurious consequences; and Halley states that he could have remained there as long as he pleased, for anything that appeared to the contrary. Besides, the whole cavity of the bell was kept entirely free from water, so that Halley sat on a bench, diametrically placed near the bottom, wholly dressed, with all his clothes on. He only observed that it was necessary to be let down gradually at first, about twelve feet at a time; and then to stop and drive out the water that entered, by receiving three or four barrels of fresh air, before he descended further. When arrived at the required depth, he let out, by the cock in the bell, a quantity of hot impure air, equal to the quantity of fresh air admitted to the barrels, when the foul air rushed up from the valve with such violence as to make the surface of the sea boil, and cover it with a white foam, notwithstanding the great weight of the water above. "Thus," says Halley, "I found I could do anything that was required to be done just under us; and by taking off the stage, I could, for a space as wide as the circuit of the bell, lay the bottom of the sea so far dry, as not to be over shoes on it. And by the glass window so much light was transmitted, that when the sea was clear, and especially when the sun shone, I could see perfectly well to write or read, much more to fasten or lay hold on anything under us to be taken up. And by the return of the air-barrels I often sent up orders, written with an iron pen on small plates of lead, directing how to move us from place to place, as occasion required. At other times, when the water was troubled and thick, it would be as dark as night below; but in such case I have been able to keep a candle burning in the bell as long as I pleased, notwithstanding the great expense of air requisite to maintain the flame."

Having by these ingenious contrivances removed the principal difficulties attending the use of the diving-bell, Halley foresaw its extensive utility. He adds: "This I take to be an invention applicable to various uses, such as fishing for pearl, diving for coral, sponges, and the like, in far greater depths than has hitherto been thought possible. Also, for the fitting and planning of the foundations of moles, bridges, etc., upon rocky bottoms; and for the cleaning and scrubbing of ships' bottoms when foul, in calm weather at sea. But," he adds, "as I have no experience in these matters, I leave them to those that please to try." To several of these purposes the diving-bell has, since the date of this paper (1717), been applied with great advantage.

Next, in 1732, Martin Triewald, a Swedish "Captain of Mechanics," expressed an opinion that no apparatus but that on the principle of the diving-bell could be safely used at great depths; and he mentions a man, then sixty-three years old, who had followed the business of diving with the common bell ever since he was twenty. Triewald's diving-bell was of copper, tinned inside, smaller than Dr. Halley's bell, and managed by two men. A stage for the diver to stand upon was suspended at such a depth below it, that the man's head could be but little above the level of the water, where the air is cooler and fitter for respiration than in the upper part of the bell; and a spiral tube was attached to the inside of the bell, with a wide aperture at the bottom, and a flexible tube and mouthpiece at the top, so that when the diver was up in the bell he might inhale cool air from the lower part, exhaling the foul air by his nostrils. Dr. Halley's air-barrels are applicable to a bell of this construction. Instead of windows of flat glass, Triewald used convex lenses to admit light to the bell. They are used to the present day. In clear weather they have been known to concentrate the sun's rays so as to burn the labourer's clothes inside the bell, when exposed to the focal point, and this when the machine was twenty-five feet under the surface of the water.

In 1775, Mr. Spalding, a grocer, of Edinburgh, experimented with Halley's diving-bell, with a view to recover property from a wreck on the Fern Islands; and he made certain improvements on Halley's bell, for which, in 1776, the Society of Arts rewarded him with twenty guineas. The improved bell contrived by him was so light that, with the diver, and weights attached to the rim, it would not sink. The necessary weight added was suspended from its centre by a long rope, which was so mounted on pulleys that the diver could either draw the balance-weight up to the mouth of the bell, or allow it to fall considerably below it. Thus, by letting the weight down to the bottom, the divers could anchor the bell at any required level, or prevent its further descent if they perceived a rock or part of a wreck beneath it, which might otherwise overturn it. Also, by hauling in the rope while the weight was at the bottom, the persons in the bell might lower themselves at pleasure. Then, near the top of the bell, a horizontal partition divided off a chamber that might, by openings and valves, be filled either with water or air from the lower part of the bell, so as to alter the specific gravity of the whole machine, and thereby cause it to ascend or descend as required. The bell was supplied with air by an apparatus resembling Halley's; and ropes, stretched across the bell, were used instead of seats and platforms for standing on. Thus the persons in the bell were enabled, in case of accident, to raise themselves to the surface without any assistance from above. A long-boat carried the signal-lines and tackle for working the air-barrels. Mr. John Farey, jun., next improved Spalding's apparatus by making the upper chamber without valves, and used it as a reservoir of condensed air, to be filled by forcing-pumps in the partition, besides other provisions. Farey also recommended that the men should be attached by ropes to the bell, so that, in case of falling, they should not sink.

Smeaton was the first to apply the diving-bell in civil engineering operations, in 1779, in repairing the foundations of Hexham Bridge. The bell used on this occasion was an oblong box of wood, supplied with air by a pump fixed on the top. In Ramsgate harbour this was used at a great depth, the supply of water being forced through a flexible pipe by a forcing-pump in a boat. This bell was of cast iron, and it weighed 50 cwt. Since Smeaton's time the diving-bell has been employed with great advantage in submarine works—sometimes in situations in which a coffer-dam could not be constructed, or the required operations performed by any other means. The mode of suspension differs according to circumstances—over the side or end of a vessel, through an opening in the centre of a barge, from framework between two barges, or from a scaffolding supported by piles. The operations upon the wreck of the *Royal George* at Spithead were first surveyed by the diving-bell in 1817. The celebrated Scottish engineer, John Rennie, on this occasion improved the apparatus for moving the bell in any direction.

A substitute for the regularly-constructed diving-bell was employed in the recovery of treasure and stores from the wreck of the *Thetis* off Cape Frio in 1830, by using a one-ton ship's water-tank, with eight inches of iron riveted to the bottom to give it more depth, and having attached to it eighteen pigs of ballast (17 cwt.) to sink it, when the greater part of the property was recovered.

The Nautilus submarine machine is an American improvement upon the old diving-bell. It is nearly cylindrical, with a spherical top; and the working apparatus, on board a barge floating near, consists of a steam-boiler, a cylinder or reservoir, and a condensing or air-pump. The workmen being stationed in the machine, water is admitted into two chambers, as ballast, to cause the nautilus to descend to the bottom; while the air is drawn through hose from the reservoir in the barge. As soon as the air thus drawn is sufficiently condensed, a cover to the bottom is raised, and communication obtained. Not only do persons thus remain under water for a considerable time, but should the hose communicating with the reservoir become disconnected, no danger can ensue to those in the machine, as they can, by means of the compressed air within the bell itself, expel a portion of the water, and thus enable themselves to rise to the surface.

A diving-machine contrived by Klingert, of Breslau, about the year 1800, was so arranged that it would rise or fall by the motion of a piston in a cylinder in the lower part of the apparatus, by which the diver could vary the density of the air at pleasure. A very simple apparatus to enable a person to dive without a bell or either of the machines here noticed, was invented in 1839 by Mr. W. H. Thornthwaite, of Hoxton. It consists of a hollow belt of india-rubber cloth, to which is attached a strong copper vessel, into which air is forced by a condensing syringe until it has a pressure of thirty or forty atmospheres. The belt is then put on in a collapsed state, so that it affords no buoyancy, and does not impede the descent of the diver; but when he wishes to rise he opens a valve, by which the condensed air escapes from the copper vessel into the belt. The entrance of the air expands the belt, which, when filled, affords sufficient buoyancy to raise the diver immediately to the surface.

PRACTICAL PERSPECTIVE.—XIII.

THE PERSPECTIVE OF POLYGONS.

We now proceed to study the method of obtaining perspective projections of polygons. Students who have worked through the course laid down in lessons in "Projection" will have no difficulty in realising the two plans drawn under the picture-line; that of Fig. 63 as the plan of the hexagonal prism standing on its end, and that of Fig. 64 as the plan of the object when lying on its side.

We require, in the first instance, to put into perspective the plan of Fig. 63, and to do this we must first enclose the regular hexagon, A B C′ D E F, by the rectangle G H I J.

This rectangle is then put into perspective in the usual method, by drawing lines from H and I to the centre of the picture, by describing the quadrant J J′, and from J′ drawing a line to the point of distance, cutting I C in *j*; then a horizontal line from *j* will cut H C in *g*, and will thus give the perspective projection of the containing rectangle.

Now from C′ and D draw lines to the centre of the picture, cutting *g j* in *a* and *f*. The line *a f* is then the distant side of the hexagon corresponding with C′ D in the picture-line.

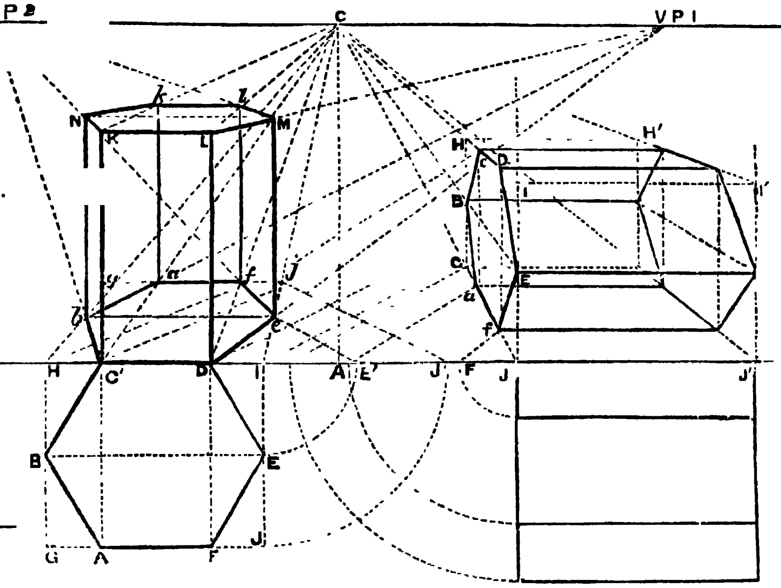


Fig. 63.

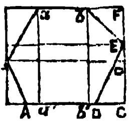


Fig. 65.

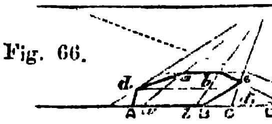


Fig. 66.

From I describe the quadrant E E′, and from E′ draw a line to the point of distance, cutting I *j* in *e*.

From *e* draw the horizontal line *e b*.

Join C′ *b*, *b a*, also D *e*, *e f*, and these, with the two lines C D and *a f*, already drawn, will complete the plan.

The student, on examining this figure, will be again reminded of the principle already laid down, that all lines which in the object are parallel to each other vanish in the same point; for he will see that the lines in the plan which unite A C′, F D, G H, and I J, being at right angles to the picture-plane, converge to the centre of the picture, and that the lines D *e* and *b a*, which in the plan are parallel to each other, converge to VP1 in the projection, whilst C′ *b* and *e f* converge to VP2.

Before proceeding with this figure, we may call attention to the fact that the perspective projection of the plan represents the original figure as if turned over on the line H I, so that the points which in the plan are in the foreground are seen in the distance in the perspective projection. In this figure, which is equilateral and equiangular, this is of no consequence, but under other circumstances it might be important that the points in the near side of the plan should be shown in the foreground in the projection, and therefore another method is shown in Fig. 65, which will apply to irregular as well as to regular figures.

Let Fig. 65 be the plan of an irregular hexagon which is to be put into perspective.

Having drawn around it the containing rectangle, and having put this into perspective, as shown in Fig. 66, mark the points A and B for the nearest side of the figure.

Now in Fig. 63 lines drawn to C from the points corresponding to these gave the width of the distant side, but in the present case this would not answer this purpose, for the distant side, *a b*, is of a different size from the near one, A B.

It is therefore necessary to set off the real width, *a′ b′*, on the picture-line (Fig. 66), and lines drawn from these to the centre of the picture will cut the distant line of the containing figure in *a* and *b*, the points required.

From C set off D, the distance of the point D from the foreground, and draw a line from D to the point of distance, cutting the line C. From this intersection draw a horizontal line, cutting the side of the containing figure in *d*.

Join A *d* and *d a*.

From C set off the length C E (taken from Fig. 65), and draw a line from E to the point of distance, cutting the line C in *e*.

Join B *e* and *e b*, completing the figure, which, as will be seen, is not reversed.

We now return to Fig. 63, with the view of completing the prism. On C′ D raise perpendiculars, C′ K and D L, and join K L. This will give one of the vertical sides of the prism, parallel to the picture-plane.

At *b* and *e* erect perpendiculars.

Now it is evident that the prism consists of six equal rectangles, and that as K L is parallel to C′ D, the upper edges of all the sides will be parallel to those immediately beneath them; and as it has been shown that all lines parallel to each other vanish in the same point, it will be evident that lines drawn from K and L to VP1 and VP2 will give the edges L M and N K, which in the object would be parallel to D *e* and C′ *b*.

From *a* and *f* erect perpendiculars; from K and L draw lines to the centre of the picture, cutting them in *k* and *l*; and join *k l*.

Then the rectangle *a f k l* will be the perspective representation of the distant side of the prism, which, like C′ D K L, is parallel to the plane of the picture.

Join M *l* and N *k*, which will complete the top of the prism; and it will be seen that these lines produced will end in the same vanishing point as the other edges of the object to which they are parallel.

Fig. 64 is the perspective projection of the same prism when lying on one of its sides, so that its hexagonal end is at right angles, and its long edge is parallel to the plane of the picture. It is hoped that previous practice will have enabled the student to work this study without the diagram being completely lettered, and with but few instructions.

The plan is, in the first place, to be projected, and at J the end elevation of the enclosing rectangle is to be put into perspective. This process is also to be carried out at the other end of the plan, and a solid rectangular block will be formed, which will seem as a case containing the prism.

Next, mark from J the points F and A, which may be done by describing quadrants from J; and from F and A draw lines to the point of distance, cutting J C in *f* and *a*. At these points draw perpendiculars, meeting I H in C and D.

On the perpendicular J mark off the height E, and from that point draw a line to the centre of the picture, cutting G H in E.

Join *f* E, E D, D C, C B, B *a*, *a f*, and so complete the end of the prism. The opposite end will be projected by simply drawing horizontal lines from the points already formed, to meet the sides of the containing figure.

Exercise 55.

The scale is ¼ inch to the foot; height of spectator, 6 feet; distance, 16 feet.

Subject, a prism, the ends of which are regular hexagons of 3 feet side, and the length of which is 8 feet.

Put this object into perspective when at 4 feet on the left of the spectator, its end being vertical and at right angles to the plane of the picture.

Exercise 56.

Put into perspective the same object when lying at the same distance on the left of the spectator, but 10 feet within the picture.

Exercise 57.

Give the perspective projection of the same prism when lying on one of its sides, its hexagonal end being in the foreground and parallel to the picture-plane, the nearest angle being 6 feet on the left of the spectator.

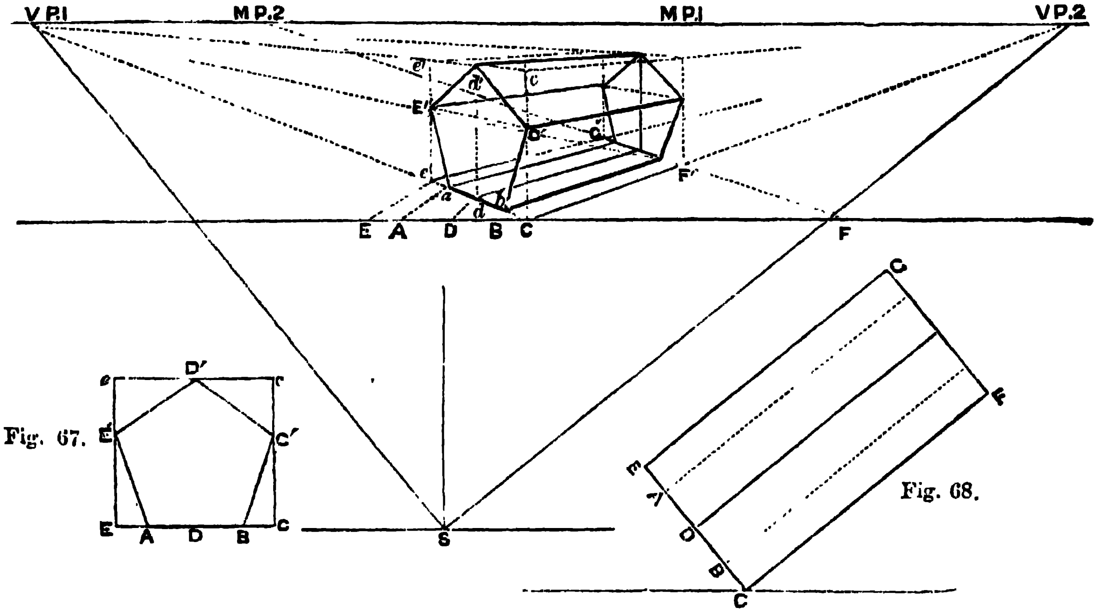


Fig. 67.

Fig. 68.

Exercise 58.

Put into perspective the same prism when lying at 5 feet on the right of the spectator, its hexagonal end being parallel to and at 8 feet within the picture.

Exercise 59.

Give a perspective view of the same prism when standing on its hexagonal end, at 4 feet on the right of the spectator, and 6 feet within the picture, the surface facing the spectator, and also that beyond it being parallel to the picture.

We now propose to show the method of projecting polygonal objects when placed at angles other than right angles to the picture-plane.

The subject of this lesson is a pentagonal prism, of which Fig. 67 is the end elevation, and Fig. 68 the plan.

Having found the vanishing-points and measuring-points, according to the position of the plan C E G F, and having projected the plan, enclose the end elevation, A B C′ D′ E′, in the rectangle C *c e* E, and put this into perspective as in Fig. 64.

Mark on the picture-line the points A, B, and D, and from them draw lines to the measuring-point, cutting C *c* in *a*, *b*, and *d*.

The length *a b* will be the perspective representation of the base of the pentagon, and a perpendicular drawn from *d* will cut *c e′* in *d′*, the upper angle of the pentagon.

Now on the perpendicular C mark off the height C′, and draw a line to the vanishing-point, cutting *c e′* in E′.

Join *a* E′, E′ *d′*, *d′ c′*, *c′ b*, which will complete the perspective projection of the pentagonal end of the prism.

The distant end will be projected by drawing lines from *a*, *b*, *c′*, *d*, *e*, to VP2, cutting the sides of the distant containing figure, as in the former example.

Exercise 60.

Put into perspective a pentagonal prism lying so that its end is at right angles to the plane of the picture, at a given distance on the right of the spectator and from the foreground. Scale and measurements at pleasure.

Exercise 61.

Give the perspective projection of the same prism when lying so that its edges are at right angles to the plane of the picture—the object to be on the right of the spectator and within the picture.

Exercise 62.

Put into perspective the same object when lying on one of its sides, so that its pentagonal end is vertical and at 50° to the picture-plane, the object being placed on the left of the spectator and in the immediate foreground.

Exercise 63.

Give the perspective view of the prism when lying so that its pentagonal end is at 40° to the picture-plane, at a given distance backward, and on the right of the spectator.

Exercise 64.

Scale, ¼ inch to the foot. Height of spectator, 6 feet; distance 18 feet.

Subject, a prism, the end of which is a regular pentagon of 2 feet side, and the length of which is 2 feet.

Put this prism into perspective when standing on its end, one of the angles of which is at 6 feet on the left of the spectator, and of the two adjacent sides (that is, the two sides meeting at this angle) the one nearest the spectator recedes from the picture at 30°.

Exercise 65.

Give the perspective projection of the same object under the same circumstances, but at 5 feet on the right of the spectator, and 8 feet within the picture.

SANITARY ENGINEERING.—VI.

GAS-METERS.

In our previous papers upon gas we have given some idea of the method of its manufacture and distribution; its applicability to small establishments, under the head of "Private Gas-Works;" and also some idea as to its practical use in lighting large interiors, under the head of "Sunburners." The object of our present paper is to give a short account of the way in which the gas we burn is measured, and the mechanical appliances available for that purpose. Water supply and payment, throughout the metropolis at all events, are regulated by an arbitrary set of rules entirely out of the control or supervision of the general consumer. The house is rated at a certain figure, and whether more or less water is consumed the payment is the same. But with gas the case is different in the great majority of instances. As far as private consumption is concerned, the gas is measured before it is burnt; in other words, it is burnt by meter, and the consumer pays for what he burns—no more and no less. How is the quantity ascertained? This we shall now proceed to show, premising that the motive power of the measurement is the pressure of the gas itself. In a former paper describing the gas "regulator," we indicated how the pressure of the gas, by the action of a valve, could be brought to bear upon the "quantity" of gas delivered and the amount of the supply, and then regulate the consumption; and the same power, the pressure at which the gas is supplied, is utilised by the machinery we shall describe in the sequel to register its own volume, and record the quantity consumed.

The principle thus broadly stated may be adopted either with the aid of water or without. Where water is used as the medium through which the gas is admitted, the machine is called a wet meter, and where no water is required, a dry meter; each system has its peculiar advantages for different purposes. The simplest form of wet meter is a horizontal cylinder closed at the end, and encased within another in which it revolves; the inner cylinder is divided into what may be called quadrants, by a series of partitions passing through its axis, and showing in section like the spokes of a wheel; and into one of these quadrant spaces at a time the gas is introduced by the supply-pipe at the water-level. As the gas enters the section of the cylinder, it gradually, by its pressure, forces up the partition, and, as we may say, turns the wheel. When a certain point in the revolution is reached, an opening is provided into the external case of the meter, the gas passing into the pipes on the other side; and the gas in the quadrant being thus released, the section below it becoming subject to the same action, is in its turn raised by the pressure of the gas, and discharges its volume of gas in the same way. In the case before us, supposing the cylinder divided into four, when each of these has been filled and discharged a revolution is completed, and a certain number of cubic feet of gas have been passed forward for consumption. The cylinder is made to revolve upon an axis, which projects beyond the internal casing, and on which is fixed a toothed wheel, which, by an ingenious arrangement of clockwork, is made to register the number of revolutions, and is so arranged that on the series of little dials on the front of the upper portion of the gas-meter, with whose appearance we are all familiar, the consumption of cubic feet is automatically registered—tens, hundreds, thousands, and tens of thousands, each being recorded on its separate dial. The inspector, who comes to take an account of the gas burnt, has only to register the figure then indicated, and his record is complete.

In dry meters the same method of registration is adopted—i.e., by means of clockwork, and the first motion is obtained by the alternate expansion and contraction of a series of movable diaphragms, the rotating motion thus obtained being registered in the ordinary way.

Nor is the amount of gas passed through any particular meter a matter of speculation; it is ascertained by actual experiment, not by any private individual, but under the absolute provision of an Act of Parliament; this is known as the "Sale of Gas Act" of 1859, and is the grand controlling power over the gas company and private individuals as far as legislation is concerned. Its action is, unfortunately, only very partial; but, as our present object is technical and not legal, we may remark that its operation will very probably be extended. It regulates the construction and stamping of meters, and provides for their deposit with the proper authorities; and to show the detail into which it goes, and the definiteness of its provisions, we will quote the second clause only, which may be taken as the key-note to the whole:—

"Clause 2. After the passing of this Act, the only legal standard or unit of measure for the sale of gas by meter shall be the cubic foot containing 62·321 pounds avoirdupois weight of distilled or rain water, weighed in air at the temperature of 62 degrees of Fahrenheit's thermometer, the barometer being at 30 inches, except as relates to contracts made before the passing of this Act, by which a different unit of measure is adopted, which contracts may not be renewed."

Inspectors of meters are appointed, and meters, after being tested according to certain provisions, into the detail of which our space does not allow us to go, are required to be stamped, the stamp attesting their correctness as ascertained by experiment. There are fines, penalties, and various other provisions in the Act, for its proper enforcement; with the details of which we will not trouble our readers.

A very important element in all matters of gas calculation is the pressure, which is thus measured:—A tube bent in the form of the letter U, with the ends open upwards, is partially filled with water, this water being perfectly level in both tubes; one end is then connected with the gas-pipe, of which the pressure has to be tested, and the power of the gas lifts the water in the other tube, and depresses it in that to which it is connected; the difference of level thus obtained is measured in inches and tenth parts of an inch. We may say that a fair average working pressure is somewhat less than an inch; but as all experiments are more delicate if made at a low pressure, the regulation testing and marking of meters and standards is fixed at a pressure of five-tenths only, or half an inch.

In localities where there is a great difference of level, the well-known tendency of gas to rise produces the result of giving a much higher pressure at the upper than at the lower portion of any range of pipes; and in practice it is found that a difference of 100 feet is about represented by an inch of pressure; so that a house situated at a height of, say, 200 feet above the gas-works, would indicate a pressure of three inches, supposing the gas delivered on the lower level at a pressure of one inch.

We now proceed to say a word or two on the comparative advantages and disadvantages of wet and dry meters; and may mention, as a fact, that the use of dry meters has much increased of late years, especially in the London district; and there are some public companies who now only fix dry meters; while throughout the Birmingham district wet meters only are used. Each system has its advocates, and we will briefly allude to the arguments on either side.

The most serious objection to the wet meter is the liability of the water to freeze, when, of course, the supply of gas is stopped; but as meters are usually within the house, a few very simple precautions will effectually prevent this happening, and it is not found in practical working to be an objection of any moment.

The next difficulty is the irregularity to which the water-level is subject from evaporation and other causes. It will be evident that if a meter measure correctly at the true water-line, should the water rise above that point, the measuring chamber through which gas passes is diminished in size, while, if the water is allowed to fall below it, more gas will pass than is measured in a precisely parallel ratio. Hence the constant recommendation of the gas inspectors to put plenty of water in the meter And here the point at which facility is afforded to any one with dishonest intentions to obtain more gas for his money than he is fairly entitled to by altering the level of the water in the meter. Many ingenious inventions have been made in the way of manufacturing "compensating" meters, which, by self-acting machinery, shall regulate their own water-level; this object being generally obtained by means of a float, which, when the water falls below a certain level, sets in motion by means of a spring or otherwise a "spoon," as it is technically called, which, from a reservoir specially provided, lifts sufficient water into the meter proper to restore the water-line. Compensating meters have been very numerous, but a great proportion of them have failed in practice from various causes; and some companies prefer relying upon the vigilance of their officers rather than resort to employing any of these methods.

Dry meters, as now ordinarily constructed, are either oblique action or direct action. In the oblique action meter the square form is usually adopted for the one side of what we may call the bellows portion, the movable part being divided into four triangular sections meeting at a point in the middle, these sections being connected by what may be called gussets of leather, and hinged all around the outer edge; when the gas is admitted the centre is gradually forced out, and the pyramidal chamber thus formed measures the gas. The metal of which the plates are formed must be of a quality to resist the corrosive action of gas and its condensation.

In the direct action dry meter the circular form is usually adopted, and a circular disc of metal is united to another all round its circumference by leather, in the same way. When the gas is admitted, the discs are gradually forced apart, and the contents of the flattish cylinder of gas between them forms the measuring unit of the meter, which may vary in size almost indefinitely from a three-light meter to a three-thousand light meter, or even larger. We may here remark that the nominal power of a meter is always very much below its actual capacity, and that any meter will safely and satisfactorily supply double at least the number of lights represented by its description. The objections to the dry meter are, that the leather with which its diaphragms are constructed is subject to variation of flexibility by change of temperature, and that, therefore, it will record irregularly at different times of the year; that it is not so lasting as the ordinary water meter, and that when out of order it is not so easily detected. There is also this objection to it, that it is not so perfectly regular in its delivery, the alternate action of the chambers sending the gas forward in a series of puffs, as it were, and not in one regular stream. This objection does not deserve any weight in ordinary practice, but in experimental uses, when it is desired to obtain an exact record of short spaces of time for purposes of comparison and calculation, certain minute irregularities of this kind have been known to occur.

We may mention that the immense meters now in course of manufacture for the works at Beckton—the largest gas-works recently erected—will be wet meters; the reason being, that all the large "station" meters, as they are called, having to receive the gas somewhat warm, with its full proportion of tarry deposit, the wet form of meter is adopted for the reason that a certain amount of deposit, which always takes place at this point, is more readily removed from a wet meter. In ordinary house meters this does not take place, and therefore dry meters may be safely introduced.

We cannot attempt to decide in favour of either, but have endeavoured to state, as fairly as we can, the arguments on either side of the question of "wet meters *versus* dry."

OPTICAL INSTRUMENTS.—X.

BY SAMUEL HIGHLEY, F.G.S., ETC.

APPARATUS EMPLOYED FOR EDUCATIONAL DEMONSTRATIONS.

It may seem strange, to some absurd, that we should ask learned teachers to devote serious attention and consideration to that reminiscence of the nursery, the galanty-show—to that toy of our boyhood, the magic lantern; but many scientific things when first discovered, either from their remarkability or beauty, have excited public interest only to the extent of being regarded as pleasing toys, till in the course of time their practical value has been discerned, and they have ranked thereafter among the implements of applied science. Such was the globe of water, magnifying in distorted form the fly or flower, till in the hands of science it sprang into that exquisite refinement on optical knowledge—the microscope—the discoverer of hidden worlds of life, and the seat or form of disease within the inmost walls of the human frame.

Such the kaleidoscope, the tin case with its bits of coloured glass, regarded long as only a wonder from the fair, till in practical hands we find ourselves indebted to its aid for many of the beautiful geometric designs which ornament our walls or floor.

Such the camera-obscura, the discovery of Baptista Porta of Padua, till the progress of chemical knowledge revealed to us the means of fixing its fleeting images; and even then its light-imprinted products, together with their adjunct the stereoscope, were little thought of in their practical and educational applications till recent days.

So with the magic lantern. Who is there over forty years of age who cannot remember in the days of his youth questionable-looking men going through London streets or country towns, crying "Galanty Show! Galanty Show!" as soon as damp and dreary winter set its mark upon the waning year? Who forgets how crude the apparatus was, suggesting a converted tea canister, illumined by a smoky, fat-trimmed lamp, or how coarse but laughter-moving the stock of slides—old Joe Grimaldi rolling his eyes—skeleton Death that raised his dart—the terrific upper and under-cut combat between the Englishman and the Frenchman—the fierce Turk's head that came out of the lily, and the black woman out of the cauliflower—all done, as we are assured, by wonderfully complicated mechanism, that cost a mint of money? Who can forget that party-spirit, moving scene of all the parish hanging on to the respective tails of the two fighting dogs or the never omitted "Pull Devil—Pull Baker," that wound up the exhibition? Ah! *tempora mutant mores.* Skeletons have gone out of fashion—and the D—— must never be mentioned to ears polite now-a-days, much less sold as a marketable commodity in the shape of a slide for the magic lantern. Then came a step towards improvement on such primitive entertainments in the shape of the "Phantasmagoria," that excited general wonderment at the old Adelphi Theatre, with its awe-inspiring effects. A few years later, and Child's dissolving views at the Adelaide Gallery, Colosseum, Alhambra, and the Polytechnic, evidenced a great advance in the right direction, and led to the production of the finest hand-painted slides and mechanical effects that have ever been produced for the magic lantern, as much as fifteen and twenty guineas each having been paid to the artists who produced them.

In recent years came the application of photography to the magic lantern, and it became apparent that that which had only been employed for mere amusement was destined to become, in the hands of the professor and schoolmaster, an important philosophical instrument of great educational value; yet I am surprised to find how few there are among those whom it most concerns—viz., the professed "educationists" of the day—who are cognisant of the extent to which the magic lantern may be employed for school teaching and class demonstration. By the aid of the magic lantern we can deal with beams of parallel, converging, or diverging rays of light, which, brought to bear upon suitable apparatus and appliances, enables us to exhibit the most important optical phenomena, and demonstrate the laws of plane and polarised light deduced therefrom.

Aided by mechanical contrivances and transparent orreries, the astronomer can avail himself of the lantern for illustrating his discourse on those vast and unlimited realms of space beyond our own globe, which are studded with other planets, star-groups, comets, and meteors; while availing himself of photography, he can present to his audience the self-depicted portraits of the sun and moon, the phases of eclipses, those mysterious protuberances that surround the sun's edge and extend to a vast height into its photosphere, the dark spots that travel over the sun's face, and the spectra of the heavenly bodies.

It is when photography is thus applied to the production of transparent diagrams for the magic lantern that the educational value of that instrument for a wide range of illustration becomes palpable. Within a disc three inches in diameter, all the details of a microscopic object of the most complex structure—the crevassed range of the Mer de Glace, or the wide-angled landscape of the Falls of Niagara—may be clearly depicted in a manner that could not be approached, much less rivalled, by a hand-painter, even if a surface four times the size of that specified were given to him to work on, which would then entail a lantern four times the size of that required for the photograph, and increased bulk of apparatus implies increased expense in every direction.

Undoubtedly many subjects have been truthfully and artistically produced for the magic lantern by the hand-painters; but can any artist (even if he be a pre-Raphaelite) for one moment pretend to cope with Dame Nature in her artistic moods, or hope to introduce the amount of detail she, with her undulating brushes of light, fixes upon the film which her assistant, the chemist, has prepared for her? For it must be borne in mind, that while the artist delights in broad effects, the teacher of science regards *detail* as a *sine qua non*, their aims being different; and when we call upon Nature to depict her treasures with her own pencil, another requirement of the naturalist is ensured—the *truthfulness*—for we know our studies are then delineated by a faithful and an unbiassed hand. I have long been impressed with the conviction that a lecturer on natural history—and even on pathology—would welcome as a boon truthful transcripts of Nature that could be packed in a small space, and then shown by means of a lantern on a scale sufficient to arrest the attention of the student, for all persons who have had any experience in scientific educational matters know the value of appealing to the eye. Book knowledge, or that experience gained even from the most graphic descriptions, is but of slight value to the student who would become a true naturalist. He must see—if possible, handle—the objects of his study.

The next best thing to this, is to be familiar with the most accurate delineations of the forms he wishes to become acquainted with; and here Photography offers her aid, and the magic lantern popularises her efforts. This mode of projecting on a screen enlarged delineations of the objects described by a teacher is very impressive, as the luminous diagram is of such a size, that every student in the largest lecture theatre can discern the most minute details, which is more than can be said of the ordinary paper diagrams usually placed before a class. But beyond this, when the photographs have been taken direct from Nature or from artistic productions correct as to the rendering of light and shade and angle of view, the image stands forth on the screen with all the roundness of Nature and perfect stereoscopic effect. Again, as only one subject is presented at a time, the attention of the student is fixed upon the object of the lecturer's description, and the listless eye cannot wander from one picture to another, as is too often the case when a number of paper diagrams are displayed at one time. There is one thing, however, that photographs cannot, as yet, effect—it can draw our pictures, but it cannot paint them. The day may come, however, when even that apparent miracle may be accomplished, for we must not forget that that great master in science, Michael Faraday, who passed from among us, not great in years, but great in the esteem of men, has bequeathed to Warren De la Rue the daguerreotype presented to him by Becquerel, whereon Nature had reproduced a coloured figure from her own spectral palette; and that precious specimen exists, unfaded—a promise for the future!

If we take a survey of the departments of science in which the lantern can be employed for class demonstrations, we shall find that

The mineralogist can employ photographic lantern slides for projecting on the screen large diagrams of chemical formulæ or tabular views of the classification of minerals—the spectroscopic characteristics of the elementary bodies—the typical forms of the crystallographic systems, and, by means of the opaque lantern, the characteristic forms and colours of minerals and rocks. By the lantern polariscope he may show the depolarising, dichroitic, uniaxial, biaxial, or tesselated characters of crystal sections; or by the lantern microscope he may show the particles of matter in the very act of grouping themselves under the force of crystallisation—the order of the magnetic curves, the action of weak currents on the needle galvanometer, or the acoustic figures of Chladni, Savart, and Lissajou—the decomposition of water into its constituent elements and their volumetric proportions, together with many other chemical, physical, and morphological demonstrations.

The botanist, either by photographs direct from Nature or from carefully-made drawings, or with preparations of the objects themselves (as the case best admits of), may display the specific character of plants—groups that illustrate the great natural divisions of the vegetable kingdom—their microscopic characters and geographical distribution—the absorption spectra of vegetable infusions, with other physical and chemical characteristics of plant-life.

The zoologist by the same means may demonstrate the osteology, the anatomy, microscopical characters, typical structure, and typical forms of the great natural divisions of the animal kingdom, and place before his students groups of animals characteristic of the regions of Europe, Asia, Africa, America, and Australia, and the ethnological types that characterise the same geographical divisions of our earth. As a rule it is preferable to take photographs direct from the living animals, as Haes has done in his admirable series from the Zoological Gardens, but in many instances this is impossible, and in some cases a diagrammatic treatment of the subject is preferable. This specially holds good with most of the oceanic forms of life; for when out of a sufficient bulk of their native element they collapse and look anything but as if they had been depicted "from the life."

Again, from the rarity of the subject desired, it may be necessary to resort to engravings; but no expense should be spared to procure them from the works of the best authorities, and in such style of execution as is to be found in the works of the Ray and Palæontographical Societies. In other cases, such as in representing the mollusca, the objects should be modelled in wax in connection with the real shell of the species, and the same applies to the tubed annelids.

The anatomist may avail himself of the method now advocated for showing *very large* diagrams of the various parts of the animal frame, *preparatory to showing the parts themselves*,* and so preparing the students for the points they should then give special attention to—a matter of grave importance when demonstrations have to be made on the dead body in hot climates.

To secure negative photographs of anatomical subjects, I may here draw attention to a possible difficulty, and the means of surmounting it.

Some years since I made an attempt at St. Bartholomew's Hospital to photograph anatomical subjects that had been carefully prepared for me by Mr. Luther Holden; but, though from one to twenty minutes' exposure was given, nothing but a faint image presented itself. I first attributed this extraordinary failure to the miasma of the dissecting-room, but on the subject being photographed out in the open air, a fine negative was obtained. Our failure was really attributable to the yellowish light reflected from the buff walls common to dissecting-rooms, such yellowish light making little or no impression upon a sensitive photographic film; and this gives us a hint, if it be thought advisable to employ photography systematically at our hospitals. The walls of the operating-room must be left white or coloured blue—not that that colour will add any actinic power to the light reflected from such surface, for it is not an uncommon error amongst photographers to believe that by allowing the light of heaven to pass through blue glass increased actinic power is secured to their operating-rooms; but it must be observed, though a yellow glass will stop the progress of the chemical rays, a blue glass will add nothing to a passing beam, whether it be rich or poor in actinic rays. The same, of course, applies to reflecting surfaces.

A Russian professor of anatomy secured exquisite sections of various parts of the human body, with all the organs *in situ*, by completely freezing a subject into a solid rigid mass before making the desired longitudinal and horizontal dissections. The various sections were then photographed, and the resulting diagrams are admirably suited for lantern demonstrations.

The physiologist may make the heart or lungs of a man or animal write its rhythmic or irregular action on a piece of smoked glass, and the result can then be shown as a large diagram by aid of the lantern: and besides the employment of coloured diagrams, the circulation of the blood, together with many other functions of vegetable and animal organs, may be displayed by means of suitable contrivances.

The pathologist may avail himself of photography and the lantern for placing before his class truthful records of rare cases, occurring at his own hospital or in the clinical wards of other medical schools at home or abroad. In rare surgical operations, portraits of a suffering patient may be taken at a given moment and instantaneously, when it would be an act of barbarity to call upon the hand-draughtsman to perform such office. Such photographic records have for some years past been made at the Middlesex Hospital by Mr. Charles Heisch. Dr. Balmano Squire has employed this method for the delineation of skin diseases; and Dr. Diamond, many years since, produced a series of photographic portraits, illustrating the "Types of the Physiognomy of Insanity," in many cases the progress of the various stages of mental disease being periodically recorded by aid of the camera.

The microscopist may in some cases display the minute structure of natural or artificial objects themselves on a magnified scale by means of the lantern microscope; in other cases, especially in regard to the most minute forms, by means of positive transparencies obtained from negatives of objects that have been enlarged in the camera up to three inches in diameter, according to the methods successfully carried out by Reade, Delves, Shadbolt, myself, Crookes, Drs. Maddox, Abercrombie, and Wright, Woodward, Bockett and others, which are then enlarged to any extent by the lantern—a matter that cannot be effected by the lantern microscope, as beyond a certain point of enlargement its optical aberrations become too pronounced when really great amplifying powers are employed.

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* This preparatory method applies generally to difficult or expensive demonstrations, when it is desirable to direct the attention of the student to the point to be observed when the object itself can only be shown for a limited time.

The geologist may illustrate his lectures by views taken direct from Nature of the mine and the quarry; the natural cleavage of slaty rocks, or the stratifications of aqueous deposits; the disintegrating action of the atmosphere on granite and feldspathic rock; the stupendous erosive action of water as at Niagara Falls; the volcanic cone and crater as in Piazzi Smyth's photographs of Teneriffe; the eruptive geysers of Iceland; mineral veins of eruptive rocks or metallic deposits, or the characteristics of glaciers and glacial action.

The palæontologist may show the extinct forms of animal or vegetable life that mark the boundary line of great epochs in the world's early history; the weird skeletons of mighty animals, toad-like creatures as big as rhinoceri, reptiles larger than whales, birds as long-necked as giraffes, stags of gigantic size, and elephants as great as Behemoth, with the probable aspect of such creatures in their living state, as restored from their fragmentary remains (not by fanciful or hap-hazard guess-work, but by sound inductive reasoning founded on anatomical knowledge) by Cuvier, Owen, Waterhouse Hawkins; or even entire resuscitated landscapes, including both plants and animals, as Unger of Vienna has so artistically reproduced in his "Ideal Views of the Primitive World."[*]

The art professor may avail himself of these aids to education for reproducing faithful transcripts of celebrated works of the great masters in all ages, and stereoscopic images of the gems of sculptured art where it would be impossible to deal with the original, even if cost or space permitted, and enable him to point out the peculiarities of style that characterise the various schools of ancient and modern art.

The engineer may throw upon a ten-foot disc embodiments of great triumphs in mechanical skill that in their reality cover miles of ground—whether they be the aqueducts of ancient nations, or such bridges as in recent days span the Menai Straits or American valleys—and the details of construction of engines and machines of peace or war.

School Teaching.—As yet I have only spoken of the application of photography and the lantern to scientific and artistic demonstration; but in high-pressure days like the present, when the student has enough to do to make himself familiar with all the subjects he is expected to be more than superficially acquainted with, I believe such legitimate aids to education would be found admirably adapted for facilitating the scholar's labour, especially in regard to history and geography; for what is more likely to make a lasting impression on the schoolboy's mind, than placing before him accurate pictures of the subject of his studies, on such a scale as to become impressive while appealing to the eye, and so to serve as an artificial memory, giving the next best thing to the students having seen the subject of their studies in their reality, a matter usually impossible, unless we really possessed the power of rendering them *clairvoyant*, and could then take them back into time, or a tour round the world. I am firmly convinced that schoolmasters would save time and teach better were they to make geography and history subjects for evening lectures, illustrated by the lantern.

History.—He would be a bold man, however, who would venture to suggest to an Oxford or Cambridge don the introduction of a magic lantern for illustrating the university course on history. But why not? "Because it has not been done hitherto," is not a sufficient answer in these days of rapid progress and wide reform; for by a well-selected and carefully-executed series of photographs from authentic data, we may make the student familiar with the features of those who have been celebrated for good or for evil in politics, war, literature, science and art—the aspect of the people of various nations, their costumes, their habitations, from the mud hovel to the stately palace; the chambers in which they lived, prayed, or died; the vases and artistic decorations with which they decked them; the gods they worshipped, carved out of the living rock, cast in bronze, or built up in ivory and gold, and of prodigious size; their manners and customs, their implements of daily life; how they lived during peace and at war, their arms and armour, and modes of attack upon an enemy; in what grandeur they carried their illustrious dead to the grave, preserved or dispersed their remains, and recorded their achievements in monumental sculptures—in fact, the life-history of nations from the earliest records to the present day.

In placing such surveys of man's history on earth, in the form of *existing scenes*, we appeal to the eye in a manner the most impressive verbal or printed description, solely, could never convey to the mind, and so establish a more rapid method of instruction, of a kind not so likely to pass out of the student's head after he has left school or college.

But the thin edge of the wedge *has been* inserted—not only in the schools but the *colleges* of Russia. In 1863, after the close of the International Exhibition, I read a paper before the Society of Arts on "The Application of Photography to the Magic Lantern Educationally Considered," on which occasion every conceivable branch of education was illustrated according to the system advocated. That paper attracted the attention of a young officer in the Russian artillery, who has since become, not only a distinguished professor, but inspector of the military colleges of Russia; and with the courage of youth he determined to adopt the system therein advocated for his own lectures on general history, and sought my co-operation to that end; so in 1869, I found my notions of 1862 *un fait accompli*—the great authorities on Assyrian, Persian, Egyptian, Grecian, Roman, and mediæval history being ransacked to supply the necessary data for drawings or colour, and the results were exhibited at the Society of Arts in 1869.[*]

Geography may be illustrated by maps showing the political boundaries the power of nations has set up, or the natural divisions climate and other physical causes has stamped upon our globe; portraits of the types of men who inhabit its various regions; the vertical range of animals and plants from the greatest mountain heights to the lowest bathymetrical depths of the ocean, or their horizontal distribution over the face of the earth, and their limits in latitude and longitude; the physical phenomena that characterise its several regions, such as monsoons, hurricanes, water-spouts, mirages, snow-storms, glaciers, ice-fields, avalanches, and land-slips, thunder-storms, volcanoes, geysers, whirlpools, mountain torrents, caverns, coral reefs, stalactitic formations, and basaltic islands; the physiognomy of mountain peaks in relation to their mineral constitution and other physical features of the earth's surface; the buildings that characterise different nations, from the snow-hut of the Esquimaux to the European palace, or those of peoples who have passed from the face of the earth, whether it be the pyramid of the Egyptian, the palace of the Assyrian, or the temple of the Aztec; the general aspect and characteristics of the great cities of the world, their engineering feats and art treasures; in fact, all such matters as educated people desire to be familiar with, and that give interest and vitality to geographical studies which the dry details and ever varying statistics of the old methods of instruction never imparted.

Descending to the artistic requirements of unscholastic life, what can be more delightful than to bring back reminiscences of travel, taken from our own points of view by means of the miniature cameras *at last* coming into vogue (cameras that are no longer a burden to the tourist); and on one's return from a summer trip, placing before family and friends enlarged transcripts, depicted by Old Sol, of the scenes that have given us health and pleasure. We can dwell no longer at present on subjects to which the art of photography may be usefully applied as a means of teaching in conjunction with the magic lantern, but we shall resume the subject in our next paper.

SEATS OF INDUSTRY.—XIV.

LEEDS.

BY WILLIAM WATT WEBSTER.

Although Leeds is the chief centre of the flax-spinning and linen manufactures of England, the staple industry of the town is the manufacture of woollen cloths, for which it has long been famous. Leeds, variously spelled in old records, "Loidis,"

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[*] "Ideal Views of the Primitive World in its Geological and Palæontological Phases." By Dr. F. Unger. Edited by Samuel Highley, F.G.S., etc.

[*] "On Photography and the Magic Lantern applied to Teaching History." (*Society of Arts Journal*, Vol. XVII., page 139.)

Leeds, etc., is mentioned by Bede, the ecclesiastical historian, and in the Domesday Survey; and soon after the Conquest a castle was built by Albert de Lacy on the eminence now known as Mill Hill, which was besieged by Stephen in 1139, and in which Richard II. was imprisoned in 1399, after his deposition. Leland, writing early in the sixteenth century, describes Leeds as "a pretty market town, subsisting chiefly by clothing, reasonably well builded, and as large as Bradford, but not so quick as it." The cloth trade had been introduced at least sixty years before this date. In his "History of the Great Rebellion," Clarendon speaks of Leeds, Bradford, and Halifax as "three very populous and rich towns, depending wholly upon clothiers."

Before the outbreak of the Civil War, Leeds was incorporated as a municipal borough, and in 1661, after the Restoration of Charles II. it received a charter, which was renewed by James II. in 1684. For centuries previous to and after the manufacture of cloth was commenced at Leeds, fairs were held there, at which the farmers of Lancashire and Yorkshire sold their wools and sheepskins to merchants from Hull and other ports, for shipment to Flanders, where they were worked up; a large portion of the wool finding its way back, in the shape of cloth, to the locality in which it had been grown.

Leeds is situated in the north-west of the West Riding of Yorkshire, in the middle of a fertile district abounding in coal, and possesses great natural as well as artificial facilities for trade. By means of the river Aire and the Calder Navigation, ships of 120 tons burden can come up to the town from the Humber and the German Ocean, while the Leeds and Liverpool Canal connects it with the Mersey, and railways branch out in all directions—to York, Hull, Manchester, Liverpool, Skipton, Lancaster, and two, by Derby and Lincoln, to London. The town is mostly built of brick, and the streets are, for the most part, narrow and irregular; but great improvements have been effected of late years, and in the centre and west end of the town there are now several broad thoroughfares, lined with handsome houses. On the south side of the Aire lie the extensive suburbs of Holbeck and Hunslet, which contain many large factories. The principal public building in Leeds is the new Town Hall, an elegant Corinthian structure, which was opened by Her Majesty in 1858, and which is adorned with several fine statues. The Mixed Cloth Hall, built in 1758, and the White Cloth Hall, for the sale of undyed goods, erected in 1775, are plain if not ugly edifices, but they possess a certain interest as monuments of a bygone system of trading. Previous to the opening of these halls the traders were in the habit of exposing their goods for sale on the parapets of the long wide bridge that spanned the Aire, and in an adjoining street, called the Briggate. The regulations under which the Mixed Cloth Hall was managed were very curious. This mart was built at the expense of the merchants and manufacturers, and the stands were held as freehold property. No person who had not served a regular apprenticeship to the mystery of making coloured cloths was allowed the use of the hall, which was only opened for business for one hour and a half on Tuesdays and Saturdays. "The market-bell," says one account, "rings at six o'clock in the morning in summer, and at seven in winter, when the markets are speedily filled, the benches covered with cloth, and the proprietors speedily take their stands: the bell ceasing, the buyers enter, and proceed with secrecy, silence, and expedition to bargain for the cloth they may require, and business is thus summarily transacted, often involving the exchange of property to a vast amount. When the time for selling is terminated, the bell again rings, and any merchant staying in the hall after it has ceased becomes liable to a penalty." The frequenters of the White Hall were subject to similar regulations.

Several of the institutions and charities of Leeds deserve to be noticed, among which is the Free Grammar School, founded in 1552, and rebuilt in 1860, at a cost of £15,000. This institution furnishes free instruction in classics and the elements of mathematics to the sons of all residents in Leeds, and four scholarships in Magdalen College, Cambridge, and an exhibition in Queen's College, Oxford, are open to the competition of its pupils. There is a somewhat peculiar charity in Leeds, known as St. John's Charity, and founded in 1705, which has for its object the training of girls for domestic service. Besides about a dozen smaller institutions for promoting popular education, Leeds possesses a Mechanics' Institute, in connection with which there is a library of upwards of 12,000 volumes, one of the most flourishing schools of art in the kingdom, capital day and evening schools, and a Working Men's Institute, with a large number of members, which furnishes newspapers and in-door and out-door games, and supplies refreshments at cost price, for a weekly subscription of one penny.

In 1775 the population of Leeds only numbered 17,117. In 1861 it had increased to 207,165, in 1865 to 224,025, and at the census of 1871 it had reached 259,201. This rapid growth corresponds strictly with the progress of its manufactures, and is mainly to be attributed to the development of the factory system. Leeds owes no small portion of its prosperity to the enterprise of two of its citizens, who were largely instrumental in introducing improved machinery and processes at a comparatively early period into the two principal manufactures of the town. These were Benjamin Gott, "the foremost woollen manufacturer of Leeds, and the man who helped most to form the character of the improved woollen trade of modern times," and John Marshall, the most celebrated flax-spinner of Leeds, and the founder of a family which still maintains the pre-eminence he gained. Both were of humble origin. Gott was born in 1762, and began work as a humble clerk in a small factory, but was shortly made a partner, and eventually succeeded to the entire management of the establishment. In the "Romance of Trade" it is stated that at the time of Gott's death, in 1840, "about 1,100 workpeople, aided by the most improved machinery, were employed in dyeing, spinning, weaving, fulling, and dressing cloth made of the best Saxony wool" in his factory, which was a model of wise and successful management. "One of Gott's chief merits," says the author of this work, "was the scrupulous regard always shown by him for the men in his employ, and the class to which they belonged. Beginning his enterprise just when the old ways of private work were being in great part superseded by factory labour, he strove hard to perpetuate the spirit of manly independence which had been begotten by the older institutions; and from first to last he encouraged the private workers to bring him their wares, and use him as their agent in disposing of them."

John Marshall, born in 1765, was a shop-boy at the time when he began to devise improvements in spinning machinery, and he was only twenty-three years of age when he started a small mill at Meanwood, near Leeds, with money supplied by two partners. It was in 1787, the year before this mill was built, that John Kendrew and Thomas Porthouse invented flax-spinning machinery, at Darlington; and soon after this similar machinery was introduced and used at Leeds. In 1791 Mr. Marshall removed to Leeds, and built a modest flax-spinning factory at Water Lane, which was enormously extended during the half century that intervened before his death in 1845, and the foundation of the linen trade of the town was laid. By 1821 there were nineteen flax-mills in and near Leeds, with an aggregate of 700 horse-power, containing 36,000 spindles, and producing about 9,000 spindles of yarn per diem, and four of these mills belonged to Mr. Marshall, "forming in extent," says Mr. Warden, "a third of the whole, and equalling Dundee entirely." Little progress was made during the next ten years, there being in 1831 but twenty-four engines at work, representing a total of 705 horse-power. By 1838, however, the number of engines had increased to forty-four, and 6,430 persons were employed in the Leeds linen trade. Twenty-one years later there were in Leeds thirty-seven works devoted to the manufacture of linen, with an aggregate steam-power equal to 1,831 horses, containing 198,076 spindles and 140 power-looms, and employing 9,458 persons.

The flax-mills of the Messrs. Marshall are the largest in the world, and this firm turns out annually a greater number of spindles of yarn and a greater value of yarn and cloth than any other engaged in the trade. Their principal factory is unrivalled alike for extent and completeness. "It is," says Mr. Warden, "132 yards long, 72 yards wide, and 20 feet high. The roof consists of 72 brick arches, supported on as many iron pillars, and secured together by strong iron-work. The brick roof has a thick coating of composition, to prevent the water from coming through, and it is covered with earth, from which has sprung up a beautiful green sward. The glass domes in the roof are each of them 48 feet round, 11 feet 6 inches high, containing 10 tons of glass, in iron window-frames. The total weight of the roof is 4,000 tons. There are four steam-engines of 100 horse-power, and two of 80 horse-power, and one engine of 7 horse-power which does nothing but blow hot or cold air into the room. The building covers more than two acres of ground, and it is supposed that 80,000 persons might stand in the room. This hall is occupied for spinning and weaving by power, and the whole processes incidental to the trade, subsequent to pickling, are performed in it, the flax going in in bundles and out in bales." The goods made here, as in most of the linen factories of Leeds, are generally of the best description, comprising damasks and the like. Large quantities of linen yarn spun in Leeds are sent to Barnsley, to Ireland, and to France; and canvas and sacking, and other coarse and rough linen goods, are also made to some extent in the town and neighbourhood.

The woollen manufactures of Leeds are chiefly carried on in mills, but the factory system has not entirely supplanted domestic manufacture. There are a number of small masters who employ a few journeymen, besides the members of their own family, and keep from two to four looms at work in their houses. Public mills, on the joint-stock principle, have been erected, which enable the small masters to compete, both as regards price and quality, with the large manufacturers. At one time the small weavers put the wool through all the processes till it was made into undressed cloth in their houses, but they now generally restrict their operations to weaving. In the "Philosophy of Manufactures," Mr. Ure states that the woollen manufactures of Leeds were carried on in 1858 in 128 factories, with an aggregate of 2,924 horse-power, and employing 10,193 persons, whose average weekly earnings amounted to 10s. 6d. each. In the larger mills all the operations are performed, from the breaking of the wool to the finishing of the cloth. The woollen fabrics manufactured in Leeds comprise broadcloths—the best quality produced being now considered equal to the West of England broadcloth—ladies' cloths, kerseys, swan's-downs, etc.

The iron-works and machine shops of Leeds are very extensive, and in 1858 employed 10,909 persons, who during the year received £560,092 in wages. There were at the same date about 3,000 ironstone and coal miners occupied in the district, and 900 persons were at work in the clay-pipe and brick fields. The most important of the minor industries of the town are the silk manufactory, which in 1858 gave occupation to 550 operatives; the manufacture of leather, which then employed 2,000 persons; the chemical works, the earthenware works, and the glass-works, which employ together upwards of 1,600 persons.

PRINCIPLES OF DESIGN.—XVIII.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS (*continued*).

In my last chapter I drew attention to the principle on which all carpet patterns should be constructed as distinctive from wall patterns, and in order to impress the necessity of giving a radiating basis to the ornaments placed upon carpets, and not a bilateral structure, I made reference to the principle of plant growth, where we notice that all plants when viewed as floor ornaments, when viewed from above, are of a radiating character; whereas if they are seen as wall or vertical ornaments, they are either radiating or bilateral: this is a necessity of a carpet pattern, that it have a radiating structure, or, in other words, that it point in more than two directions.

Man naturally accustomed to tread on grass when brought into a state of civilisation, seeks some covering for his floor which shall be softer to the tread and richer in colour than stone or brick. And in our northern climate he seeks also warmth; hence he chooses not a mere matting, or lattice of reeds, but a covering such as shall satisfy these requirements.

In early times our floors appear to have been strewn with sand—a custom still lingering in some country districts; then came the habit of strewing reeds over the floor, and, on the part of the opulent, sweet scented reeds (*Acorus calamus*). And it is curious to notice, in connection with this subject, that one of the charges brought by Henry VIII. against Cardinal Wolsey was that of extravagance in the use of sweet reeds. This use of reeds was succeeded by the employment of mats of simple appearance, formed of a kind of grass, and these by the introduction of wool mats, which, at first, were chiefly imported, but afterwards manufactured in our own country. The wool mats were in their turn replaced by carpets, which gradually increased in size till their proportions became such as to cover the entire floor on which they were placed.

This brief history brings us to notice what is required of a carpet: thus, it should be soft in texture, rich in appearance, and of "bloomy" effect.

We may add to these requirements by saying that a carpet should also be a suitable background to all works of furniture or other objects placed upon it, and that in character it should accord with the objects with which it is associated in any particular apartment.

Considering more fully these requirements, we notice that a carpet should be soft. This is very desirable, for softness gives a sense of comfort, and with softness is generally combined durability; but softness can scarcely be regarded as an art-quality. Yet as the art which an object bears is more leniently viewed when the fitness of the object to the purpose for which it is intended is apparent, we may safely regard softness as a very desirable quality of a carpet.

The Eastern carpets are pre-eminent in this quality of softness, and of English-made carpets "Brussels" and tapestry are the least satisfactory in this way as usually made, they having a hard "backing." A kind of Brussels carpeting with a soft back has recently been brought out, but at present it is not general in the trade. If the carpet employed in any apartment as a floor covering is harsh in character, it is desirable to place soft felt under it (felt for this purpose can be got at carpet warehouses), or evenly spread soft hay, for by so doing the wear of the fabric will be greatly increased, and the pleasure of walking on it will also be correspondingly greater.

The next quality of a carpet is richness. No carpet is satisfactory which is "washy" or faded in appearance. There must be "depth" of effect, a "fulness" of art quality. Hangings may be delicate, wall-decorations soft in tint, but a carpet must be rich and "full" in effect.

But this richness must be of singular character, for the most desirable effect which a carpet can present is that of a glowing neutral bloom.

I hope that my language does not appear mystical to the general reader or young student. To the ornamentist I think it will be intelligible. What I wish to say is that the effect should be glowing, or radiant, or bright, as opposed to dull, quiet, or heavy; that it should be such as results from the use of a predominance of bright and warm colours, rather than of cold and neutral hues; that it should be neutral, inasmuch as it should not present large masses of positive colour, but should have an equality of rich harmonious colours throughout; that it should be "bloomy," or have the effect of a garden full of flowers, or better, of the slope of a Swiss alp, where the flowers combine to form one vast harmonious "glow" of colour. This is the effect which a carpet should present, yet it should never present flowers, imitatively rendered, as its ornamentation. Such imitative renderings are not to be produced by the ornamentist; they must come from the pictorial artist, for they are pictures. They cannot form suitable backgrounds to furniture and living objects, for they are positive, and not neutral, in their general effect. A picture, also, will not bear repetition: whoever heard of one person having two copies of the same picture in one room? Yet a pictorial group of flowers may be seen repeated many times over a floor, which is very objectionable. The effect to be produced is that of a rich "colour bloom;" but the skilled ornamentist will achieve this without violating any laws of fitness, and will gently and delicately hint at the beauty of a profusion of blossom through his tenderly-formed pattern.

Yet a carpet must be neutral in its general effect, as it is the background on which objects rest. Neutrality of effect is of two kinds. Large masses of tertiary or neutral colours will achieve its production, so also will the juxtaposition of the primary colours in small quantities, either alone, or with the secondary colours, and black or white; but there will be this difference between the two effects—that produced by low-toned colours will be simply neutral, while that produced by the primary colours will be "bloomy" as well as neutral, and if yellows and reds slightly predominate in the intermingling of colours, the effect will be glowing or radiant.

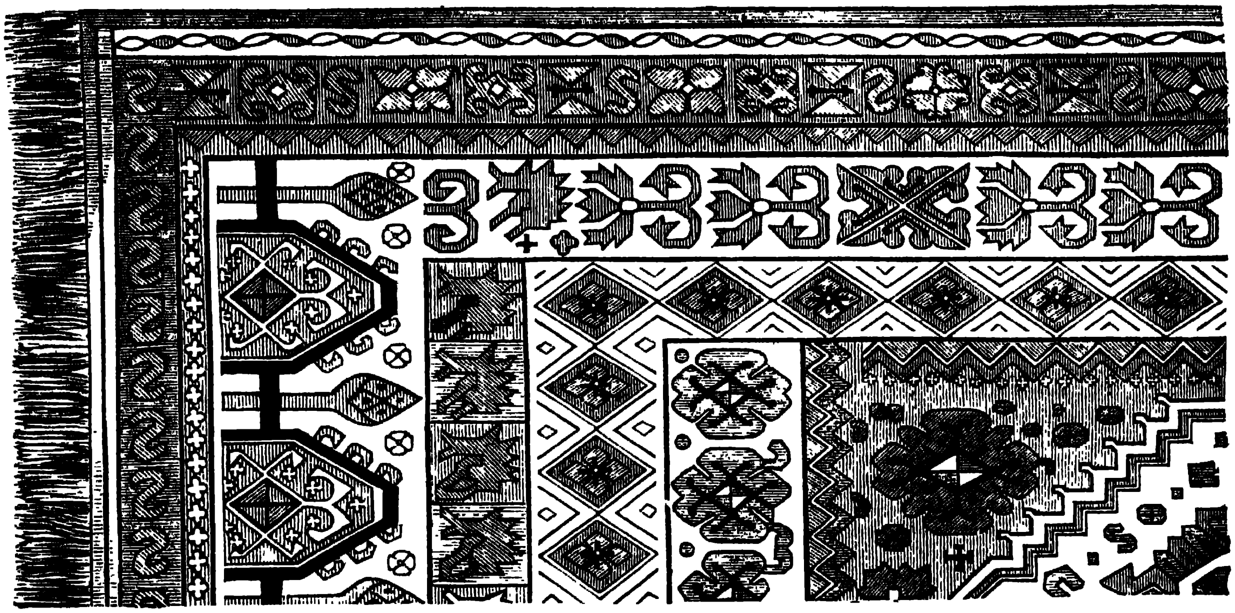


Fig. 64.

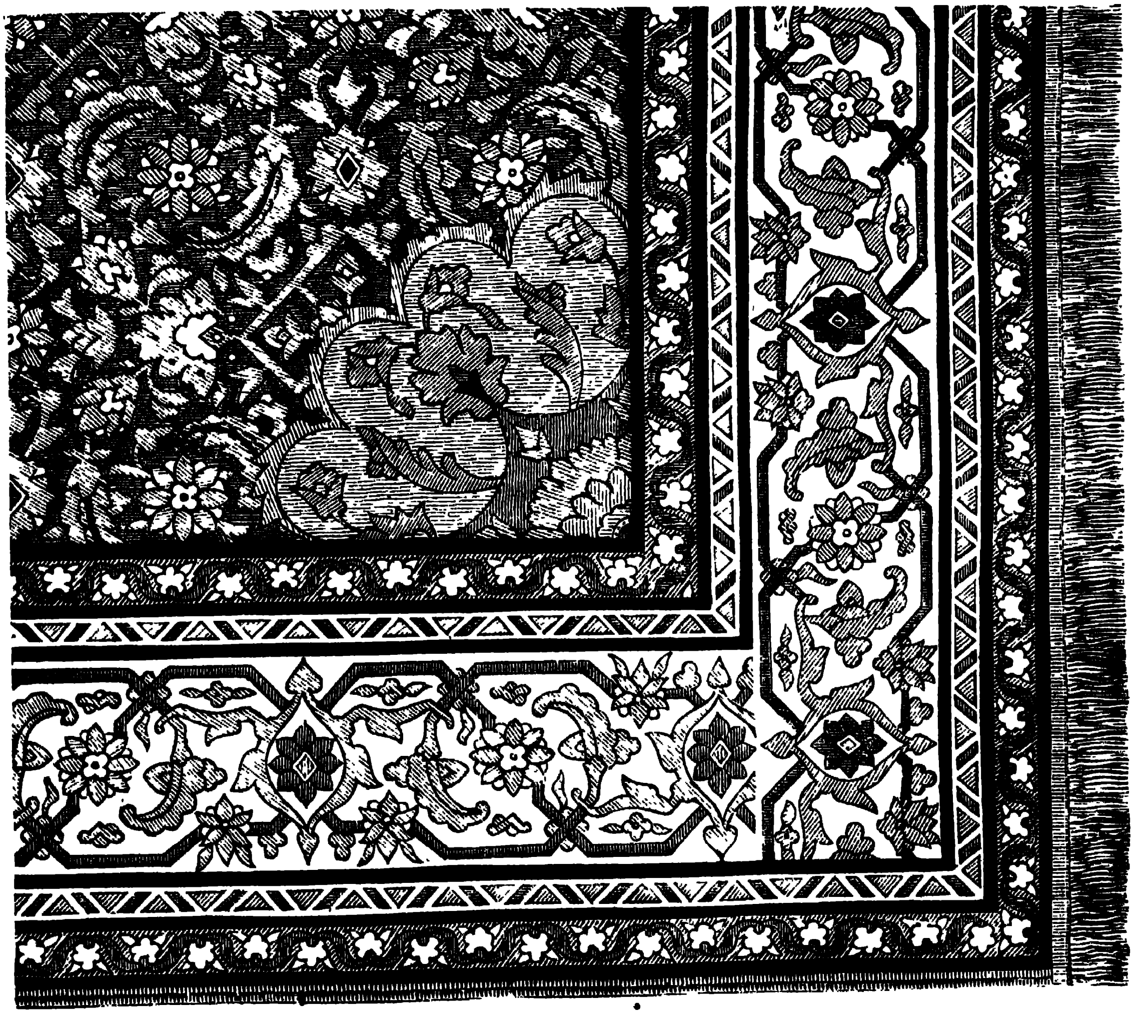


Fig. 65.

The radiant, or glowing, bloomy neutrality of effect is that which it is most desirable that a carpet should present.

This effect is rarely produced in English carpets, owing either to the want of skill on the part of the ornamentist, who is unable to produce such works; the want of judgment on the part of the manufacturer, whereby he fails to produce such patterns; or the want of taste on the part of the consumer, owing to which he buys works of a more vulgar character. I have designed six carpets for Messrs. Crossley and Sons of Halifax, which are shown in the International Exhibition now open at South Kensington, in which I have sought to realise as much of this effect as I could with six colours—the number to which I was limited by the conditions of manufacture; and fortunately these appear to be commanding a large sale, and to be setting a fashion in carpets; but those who wish to study these bloomy effects in their more perfect forms, must do so in the carpets of India, Persia, Smyrna, and Morocco, but especially in the Indian rugs.

Some of the carpets from India are perfect marvels of colour, harmony, and of radiant bloom. They appear to glow as a bed of flowers in the sunshine, and yet they are neutral in their general effect, and when placed in an apartment do not usurp a primary place, as does any pictorially-treated pattern.

This "bloom" was seen to perfection in one or two silk rugs which were shown at the International Exhibition of 1862 in London, and it was not much less apparent in some of the carpets from India shown in the Paris Exhibition of 1867, the most lovely of which was purchased by John Lewis, Esq., now a partner in the firm of Messrs. Crossley and Sons. Most Indian carpets have this colour-bloom to some extent, and few are unworthy of careful study.

Persian carpets (Fig. 64) are also models of what carpets should be; they are less radiant than many of the Indian works, but are almost more mingled in colour-effect. In pattern, many of the Indian and Persian carpets are identical, being traditional, yet in colour they differ, and both are worthy of the most careful consideration.

The Morocco carpets (Fig. 65) differ again from both those of India and Persia, and even to a greater degree than the Persian carpets differ from the Indian. In those there is often a prevalence of soft yellows and juicy yellow-greens, intermingled with reds, blues, and grey-whites, in such a manner as to produce a most harmonious and artistic effect. To the young student, and to any who may desire to cultivate his taste in respect to such matters, I say, Study the carpets of the East most carefully, especially those of India, Persia, and Morocco.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XV.—BENJAMIN HUNTSMAN.

BY JAMES GRANT.

In a work like The Technical Educator, the inventor of cast steel could scarcely be omitted. Benjamin Huntsman, prior to whose time most of the steel used in England and Scotland came from Germany, Flanders, or Sweden, was born in Lincolnshire in the year 1704. Being of a clever and ingenious turn he was bred to mechanics, and, as a lad, became chiefly famous as a repairer of clocks; thus eventually he opened a shop in Doncaster, where he was deemed the principal maker and mender of clocks in West Yorkshire. "He also undertook various other kinds of metal work," to quote Mr. Smiles, "such as the making and repairing of locks, smoke-jacks, roasting-jacks, and other articles requiring mechanical skill. He was remarkably shrewd, observant, thoughtful, and practical—so much so, that he came to be regarded as the 'wise man' of his neighbourhood, and was not only consulted as to the repairs of machinery, but also of the human frame. He practised surgery with dexterity, though after an empirical fashion, and was held in especial esteem as an oculist."

It would seem that, for his medical advice, he never took fees in return. In West Yorkshire, there are still in existence several of the clocks that were made by Benjamin Huntsman, and one of these possessed by his descendants has a pendulum of pure cast steel. In the pursuit of his multifarious mechanical callings, this ingenious man invented several new or highly-improved tools; but the inferior quality of the common German steel with which he wrought, he considered a serious obstruction, and he was thus induced to consider the means of producing a better and purer material than that which came from the Continent. At Doncaster he had commenced, in a small way, his first experiments, as the steel pendulum referred to serves to show; but in the year 1740 he removed to the vicinity of Sheffield, as he had a difficulty in procuring a sufficient supply of fuel for smelting purposes in the former town.

At the little village of Handsworth, a few miles south of Sheffield, he now began to pursue secretly his experiments, of which no memoranda or record have been preserved, neither are there any of his modes of investigation. But the progress of the work must have cost him much care, thought, and consideration, as he was totally without those appliances which were requisite, and which have been the gradual development of later times. Not only had Huntsman to discover the fuel and flux proper for his purpose, but he had to construct a furnace, and make a crucible such "as should sustain a heat more intense than any then known in metallurgy," in England at least. All those requisites which are now familiar in the process of smelting—hoops, wedges, and ingot-moulds—were as yet in the womb of the future.

Many years would seem to have been passed in unsuccessful experiments, before he obtained the purity of metal he coveted; and, curiously enough, he would appear to have hidden, by burying in the earth, many hundred-weights of steel in the manufacture of which he had failed from various causes, such as bad fluxes, imperfect melting, the bursting of crucibles, and other casualties; for long after he had passed away, these relics of his numerous failures were dug up from time to time in the vicinity of Handsworth. Cast steel is iron in its very highest state of perfection—the iron being united to carbon with a small portion of oxygen while in an elastic state; but the coarse crude or pig-iron consists of the metal combined with carbon in a material state. The great merits of cast steel are its fineness of grain, its perfect cohesion, durability, and capacity to receive a keen edge, and hence its value in the manufacture of all manner of tools, and all the implements of peace and war.

The perseverance of Huntsman was rewarded at last, and his great invention, one of the highest rank, and one which greatly contributed to forward the industrial and commercial supremacy of the British Isles, was completely perfected.

The process of making cast steel, as invented by Benjamin Huntsman, may be thus summarily described:—The melting is conducted in clay pots or crucibles, manufactured for the purpose, capable of holding about thirty-four pounds each. Ten or twelve of such crucibles are placed in a melting-furnace, similar to that used by brass-founders; and when the furnace and pots are at a white heat, to which they are raised by a coke fire, they are charged with bar-steel, reduced to a certain degree of hardness, and broken into pieces of about one pound each. When the pots are all thus charged with steel, lids are placed over them, the furnace is filled with coke, and the cover put down. Under the intense heat to which the metal is exposed, it undergoes an apparent ebullition. When the furnace requires feeding, the workmen take the opportunity of lifting the lid of each crucible, and judging how far the process has advanced. After about three hours' exposure to the heat, the metal is ready for turning. The completion of the melting process is known by the subsidence of all ebullition, and by the clear surface of the melted metal, which is of a dazzling brilliancy like the sun when looked at with the naked eye on a clear day. The pots are then lifted out of their place, and the liquid steel is poured into ingots of the shape and size required. The pots are replaced, filled again, and the process is repeated; the red-hot pots thus serving for three successive charges, after which they are rejected as useless.

More than a century has passed since the invaluable discovery made by Benjamin Huntsman; yet the kind of fuel to which he resorted, coke, and the furnaces and crucibles he adopted for smelting—all the suggestions of his own mind—are greatly similar to those in use at the present time, and no manufacturer has, it is said, been able to surpass the quality of the steel he produced.

Finding now that the boasted metal of all other foreign markets had been surpassed, Huntsman saw that cast steel could be turned to other purposes than watch-springs and the pendulums of clocks. He offered his new metal to the cutlers of Sheffield for the manufacture of knives, tools, swords, etc.; but, one and all, they ignorantly and perversely declined to work with a metal so much harder and denser than any to which they had been accustomed. Mortified and foiled at home, Huntsman had to turn his attention to foreign markets. and soon found that the demand was so great that he could scarcely overtake the supply. This was chiefly in France, and thus, though for a time only, the merit of applying cast steel as now used belongs to the French. They were bold enough to claim the whole invention as being that of a native of France, and such continued to be long the popular fallacy, till M. Le Play, Professor of Metallurgy in the Royal School of Mines in France, after making long and careful investigations, and weighing all the evidence on the subject, arrived at the conclusion that the invention fairly belongs to Huntsman and to no French subject.

M. Le Play also showed. in his Report to the French Government, the systematic neglect which men of Huntsman's class and inventive genius have too generally received in England, and the much greater esteem in which they are held by scientific foreigners.

The Sheffield manufacturers soon saw the folly of which they had been guilty when Huntsman had fairly established his business in France, from whence his steel obtained a reputation over all the Continent, and even among the sword-cutlers of Toledo; and seeing the injury that would be done to their own trade if foreign goods were thus preferred by British as well as Continental consumers, they were arrogant and illiberal enough to send a deputation to Sir George Savile, M.P. for the county of York, requesting him to use parliamentary influence to prohibit the exporting of cast steel. Perceiving that they were inspired by self-interest only, he curtly declined, and meanwhile Huntsman had pressing offers from certain hardware manufacturers in Birmingham to remove his business and his furnaces there, to which he did not accede; and as the cutlers in Sheffield speedily found that if they would keep the French out of the market they must use the steel of Huntsman, his trade multiplied rapidly at home as well as abroad

Innumerable efforts were made by the Sheffield cutlers to elicit from him the secret he possessed, for he had no patent to protect him; and hence a kind of mystery accompanied the process of his smelting. All strangers were sedulously excluded from his works; the whole of the steel was melted there in the night, and all his men were sworn to preserve perfect secrecy. Hence the most absurd rumours soon became current; among others, that his process involved the infusion of broken bottles. He used only the best bar steel, and it came from Danemora (thirty-five miles from Upsala in Sweden), where iron mines have been constantly wrought since the fifteenth century, and the metal produced was esteemed as the best in Europe. After being brought from the mines, it was smelted by charcoal in the forges of Osterby, and prepared for exportation—the exportation of unsmelted ore being utterly forbidden by the Swedish government, then at least. Five hours formed the time requisite for Huntsman to convert the Danemora metal into pure cast steel.

An envious rival and iron-founder named Walker, who resided at Greenside, near Sheffield, is said to have been the first person who succeeded, by a pitiful deception, in copying and pirating the unprotected secret of Huntsman. Disguised as a beggar, and feigning abject misery and distress, he appeared at the foundry-door late one night, when the snow-flakes were falling fast, and the red glare of Huntsman's furnaces shed a cheerful glow over all the neighbourhood. Shivering with cold and apparent hunger, he moved the workmen's hearts to let him enter and warm himself in the works; and he was accordingly permitted to take up his quarters there for the night, lest he might perish if shelter were denied him.

"A careful scrutiny," writes the author of "Useful Metals and their Alloys," "would soon have discovered little real sleep in the drowsiness which seemed to overtake the tattered stranger; for he eagerly watched every movement of the workmen while they went through the operations of the newly-discovered process. He observed, first of all, that bars of blistered steel were broken into small pieces, two or three inches in length, and placed in crucibles of fire-clay. When nearly full, a little green glass, broken into fragments, was spread over the top, and the whole covered with a closely-fitting cover. The crucibles were then placed in a furnace previously prepared for them, and after a lapse of from three to four hours, during which they were examined from time to time to see that the metal was thoroughly melted and incorporated, the workmen proceeded to lift the crucible from its place on the furnace by means of tongs, and its molten contents, blazing, sparkling, and spurting, were poured into a mould of cast iron previously prepared; here it was suffered to cool, while the crucibles were again filled and the process repeated. When cool, the mould was unscrewed, and a bar of pure cast steel presented itself, only requiring the aid of the hammermen to form a finished bar of cast steel. How the unauthorised spectator of these secret operations effected his escape without detection, tradition does not say; but it tells us that before many months had passed the Huntsman manufactory was *not* the only one where cast steel was produced."

Despite this unscrupulous opposition, the demand for Huntsman's steel increased steadily; and thus, for the purpose of having a greater range for his works and speculations, in 1770 he removed to the village named Attercliffe-with-Darnal, near Sheffield, where he had built a large and commodious foundry, with furnaces and all requisite appliances. The Royal Society of London wished to elect him as a member, in consequence of the great merit attached to his invention of cast steel; but as this would have drawn him from the seclusion he preferred, he declined the proffered honour; moreover he believed that to have such initials after his name as F.R.S. would be opposed to the principles of the religious body of which he was a zealous member—the Society of Friends. For six years he continued to flourish, "making steel and practising benevolence," till the year 1775, when he died at the age of seventy-two, and was interred in the churchyard of Attercliffe, where a grave-stone with an inscription records the facts of his birth, death, and the brief history of his great invention.

This grave was visited by M. Le Play, the learned Professor of Metallurgy in the Royal School of Mines in France, in his enthusiasm and admiration for this humble mechanic, whose steady perseverance had enabled him to overcome all the difficulties he experienced in perfecting his great invention and discovery. The Huntsman mark on steel became a trade-mark known throughout the civilised world. His name is well-nigh forgotten in England now; but, as Sir Henry Englefield says, "were public benefactors to be allowed to pass away, like mere hewers of wood and drawers of water, without commemoration, genius and enterprise would be deprived of their most coveted distinction."

While on the subject of iron and steel, it may be interesting to mention that nowhere were they more early prized than in the East. Even in the 57th chapter of the Koran, Mohammed says that God sent down with the apostles the Scriptures, the balance, and *iron* "wherein is the mighty strength for war;" and Al Zamakhshari adds the Arab tradition, that Adam is said to have brought down with him from Paradise *five* things made of iron—viz., an anvil, a pair of tongs, two hammers, a greater and a lesser, and a needle!

TECHNICAL DRAWING.—XL.

DRAWING FOR STONEMASONS.

THE ARCH: VARIOUS FORMS OF ARCHES AND VAULTS.

An arch in masonry is a part of a building suspended over a given space, supported only at the extremities, and concave towards the plan. The general history and principles of construction of arches have been given in "Building Construction," only such portions of what has there been said are repeated as are necessary for the further investigation of the subject; and, for the rest, the student is referred to the lessons alluded to.

The supports of an arch are called the *spring walls.*

The whole of the under surface of the arch opposite to the plan is called the *intrados*, and the upper side is termed the *extrados.*

The boundary line or lines of the intrados, or those common to the supports and the intrados, are called *springing lines* of an arch.

A line extending from any point in the springing line on the one side of the arch, to the springing line on the opposite side, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the *section of the hollow* of the arch.

The vertical line drawn on the section from the middle of the spanning line to the intrados is called the *height* of the arch, as also the middle line of the arch, and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

The curved parts on the top of the section between the crown and either extremity of the spanning line are called the *haunches* or flanks of the arch.

Arches are variously named, according to the geometrical figure by means of which they are formed, as *semi-circular, elliptical, cycloidal, catenarian, parabolical*, etc.: these, as well as the *horseshoe, stilted, composite*, and *pointed*, together with the method of constructing them, have been given in the lessons in "Building Construction."

When the extremities of an arch rise from supports at unequal heights, the arch is called *rampant*.

When the upper line or side of an arch is parallel to the under line or side, it is called an *extradossed* or *concentric* arch (Fig. 363).

When the outer side of the curve is drawn from another centre, it is called an *eccentric* extrados (Fig. 364).

The term *arch* is frequently confounded with *vault*; but the distinction we shall adopt here is based on the degree of depth, an arch being a structure of no very great depth from one side to the other, whilst a vault may be unlimited. Thus we say "an *arch* in a wall," but "a *vaulted apartment* or cellar," so that a vault is an extended arch. Practically, every vault is an arch, but every arch is not a vault.

A vault is *cylindric* when its form is that of a cylinder, never greater than the half when the axis is in the same plane with the springing of the arch. It is also termed *barrel* or *wagon-headed*.

A vault in *full centre* is that which is formed of the surface of a semi-cylinder.

A vault is said to be *surmounted*, or *surhausse*, when it is formed by the portion of any curve where the height is greater than half the span.

A vault is termed *surbaise* when the height at the crown is less than half the width of the springing.

A *rampant* vault is one the springing of which is not parallel to the horizon, as in many staircases descending into cellars.

Conic vaults are, as their name implies, of the form of a cone. They may be of three kinds, according to the disposition of the axis—viz., parallel, perpendicular, or oblique to the horizon.

Spherical vaults are usually called *domes*. All domes are, however, not spherical, since they may spring from a polygonal, circular, or elliptic plan, presenting a convex surface on the outside, and a concavity within, so that every horizontal section may be of a similar but different-sized figure, and have a common vertical axis.

The word *dome* is generally applied to the external part, and *cupola* to the inner part.

It is believed that the term is derived from the Latin word *domus*, a house. The Germans call it *dom*, and the Italians *duomo*, and apply the name to the principal church of a city, although the building may not have any dome.

An *annular vault* is one of which the plan is contained between two concentric circles; its generating section may either be that of a pointed arch or of a semicircle, or, indeed, of any other curve.

A *simple* vault is one which is constructed of the surface of some regular solid, around one axis or centre.

A *compound vault* is one which is made up of more than one surface of the same solid or of two different solids, such as would be formed by two cylinders or spheres penetrating each other.

Cylindro-cylindric vaults are such as are formed of the surfaces of two unequal cylinders.

Groined vaults rise in their surfaces to the same height as two equal cylinders, or a cylinder with a cylindroid. Several of these arches or vaults will form the subjects of future lessons.

We now proceed to give the method of drawing the examples in Figs. 363, 364, 365.

Fig. 363 is the elevation of a concentric semi-circular arch. The student is reminded that in this all the joints must be radii of the circle of which the arch is one-half, and that the separate stones of which the arch is built are called *voussoirs*, the middle one being the *keystone*, and the two lowest—that is, those resting immediately on the abutments or piers—being termed *springers*.

Fig. 364.—This example shows a section of a semi-circular vault with an eccentric extrados. This system is much more solid than that shown in Fig. 363, whilst the depth at the crown is the same.

To draw the eccentric arch, the intrados A B C having been described, and the height of the extrados having been fixed at D, set off from B two-thirds, three-fourths, or even the whole length, A C—viz., to E—then, with radius E D, describe the extrados F D G. The divisions of the voussoirs must be set off on the intrados, the joints converging to the centre O.

Fig. 365 shows the manner of terminating the arch by horizontal and vertical lines. These are drawn from the points where the radii cut the extrados. When it is desired that the horizontal lines should coincide with the courses of stone, the horizontal joints are continued until they cut the radii; this is shown in the right side of the example. This method is not so good as that shown on the left side, where the pressure is borne uniformly by the whole joint; for it will be seen that an interior angle has to be cut in the under surface, into which an external angle cut in the stone beneath must fit; but if this angle is not cut with the utmost accuracy, the construction would be compromised by the transverse cracking of the stones when under pressure.

Fig. 366 is an arch formed by the segment of a circle. This method is frequently employed in the construction of bridges. It will be seen that the intrados having been divided into the required number of parts, the joints for the voussoirs, which are radii of the arc, are carried up, and are intersected in groups by the horizontal courses of the stonework.

Fig. 367 shows a semi-elliptical arch, the curve of which may be constructed in any of the various methods shown in "Practical Geometry applied to Linear Drawing." To find the direction of the joints, which must be perpendicular to the curve, divide the intrados into the required number of equal parts, and from the foci F and F draw lines to each of these points, as shown at A; bisect the angle thus formed, the bisecting line A C will be one of the joints required.

It will be seen this is an illustration of a surbaised vault, the height at the crown being less than half the width of the springing.

Fig. 368.—This is a rampant arch. To draw the intrados of this, the height of the imposts A and B being given, draw the line A B joining the imposts, and bisect it in C. At C draw a vertical line, and make C D equal to C B. From D draw a line at right angles to A B, intersecting horizontal lines drawn at A and B in E and F, which will be the centres required.

Draw the arc D B with the radius E D, and the arc D A with the radius F D.

Divide the intrados into the required number of equal parts, and the joints will be radii of the arc in which they are contained.

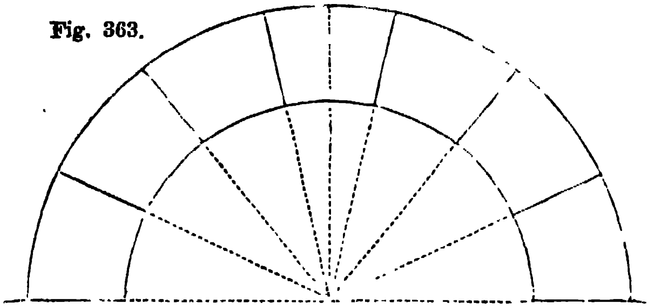
Platbands.—A platband is any flat square moulding whose height much exceeds its projecture. Such are the faces, or "fasciæ," of an architrave, and the platbands of the modillions of a cornice.

The platband of a window or door is used for the lintel, where that is made square or not much arched. These platbands are usually crossed with bands of iron when they have a great bearing; but it is much better to ease them by building discharging arches over them. The uses of both lintels and discharging arches have been explained in lessons in "Building Construction."

Fig. 369.—The whole platband of a window or door, which is simply a straight arch, must form a trapezium, A B C D, of which the upper line, or extrados, D C is, of course, the longest side; and each of the stones should be of the trapezium or wedge-like form, so that neither of them may slip between the others.

To accomplish this, divide the intrados A B into an uneven number of equal parts. Construct on A B the equilateral triangle (which form is usually adopted) A B O. Draw the line from O

Fig. 363.



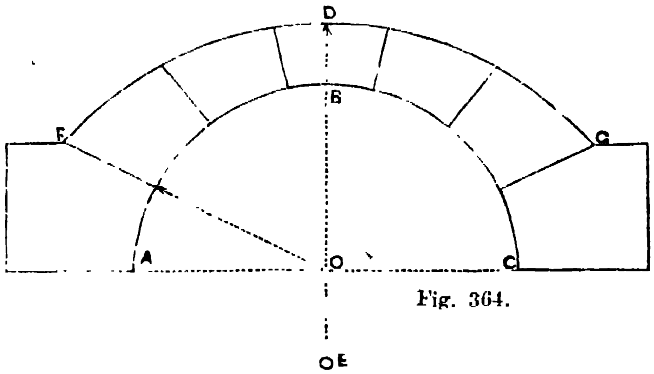


Fig. 364.

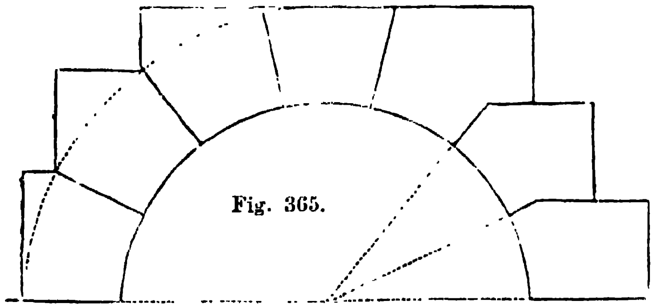


Fig. 365.

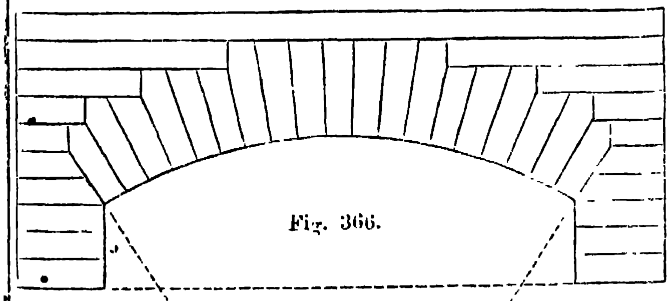


Fig. 366.

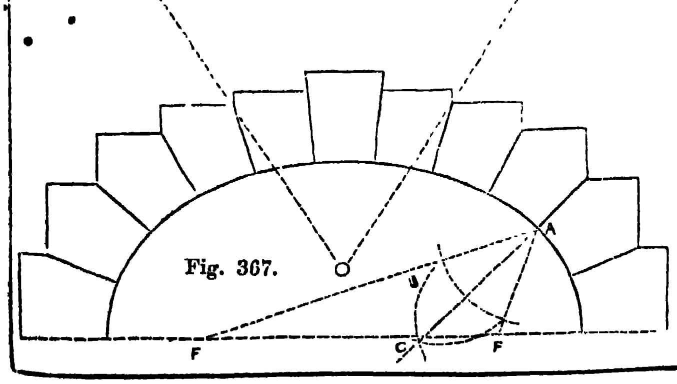


Fig. 367.

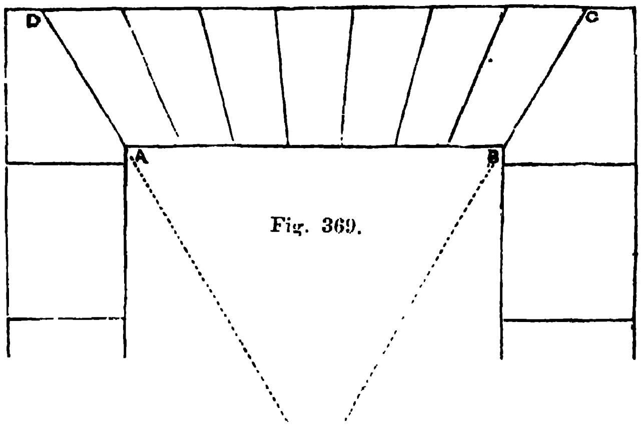


Fig. 369.

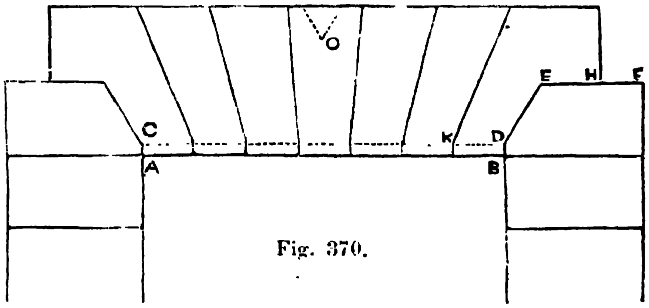


Fig. 370.

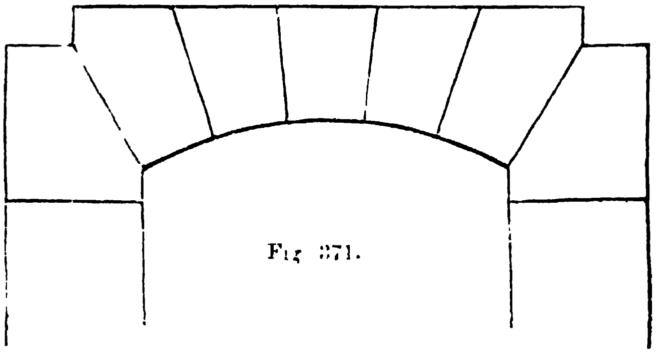
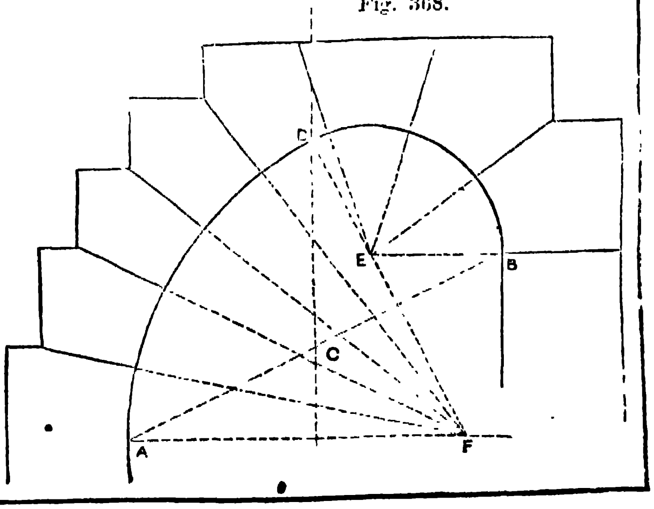


Fig. 371.

Fig. 368.



through the points in the intrados, cutting the extrados. These lines will give the keystone and the voussoirs.

Fig. 370.—In this figure another method is shown which materially adds to the strength of the arch. To construct this form, divide the intrados as before into an uneven number of equal parts: produce the sides of the piers beyond A and B, and draw the line C D. From the points of division draw perpendiculars, as K, and from D, K, etc., draw the joints. It will be observed that the pressure is thus brought to be as much as possible downward instead of outward, since the main bearing of the platband is on the horizontal top of the pier E F.

Fig. 371 is another example for drawing a similar subject, in which increased strength is given by increasing the depth of the voussoirs as they approach the keystone. The method of drawing this subject will be understood from the previous examples.

NOTABLE INVENTIONS AND INVENTORS.

XVIII.—THE DIVING-BELL (*concluded*).

BY JOHN TIMBS.

DR. HALLEY also invented an apparatus by which a man might leave the diving-bell and walk about at the bottom of the sea, his head being covered by a heavy leathern cap, like a small diving-bell, supplied with air by a flexible tube extending from the large bell. The diver was to coil this tube round his arm, and unwind it as he left the bell; and to use it as a clue to direct him to the bell in returning. The modern invention of water-proof india-rubber cloth water-tight tubes is well known. By these tubes, so long as the head-covering or helmet is above the level of the water, it will be kept full of air; and in case of having to stoop below that level, as in getting out of or into the bell, the diver has only to close a valve, by which the air in the helmet is prevented from returning into the bell. The front of the helmet is glazed, and the diver was enabled to walk by means of a weighted girdle and weighted clogs. Aquatic armour supplied with air from above, or carrying a store in its cavities sufficient to last for the time the diver intends to remain submerged, has been little used. As early as 1715, a diving apparatus, consisting of a case for enclosing the person, with the arms protruding in flexible sleeves, was contrived and used for many years by one John Lethbridge, of Newton Abbot, Devon. This apparatus was supplied with air by flexible pipes. A similar machine, contrived by Mr. Rowe, in 1753, was lowered by tackle, like a diving-bell. At Newton Bushel, Devon, an ingenious person contrived a large strong leather water-tight case, to hold half a hogshead of air, and adapted to the legs and arms, with a glass in front, so that the wearer could walk about easily at the bottom of the sea, examine a wrecked vessel, and deliver out the salvage. The inventors of this apparatus used it forty years, and thereby acquired a large fortune.

Among the early projects for submarine navigation should be mentioned Drebell's vessel to be rowed under water, which was tried in the Thames by order of James I., and carried twelve rowers besides passengers. It is described by the Hon. Robert Boyle, who states the chief secret to be "the composition of a liquid that would speedily restore to the troubled air such a proportion of vital parts as would make it again for a good while fit for respiration." But the composition of this liquid for enabling the same air to be used again and again was never made public.

Bishop Wilkins, in 1648, devised an "Ark for Submarine Navigation," in which he states "all kinds of arts and manufactures may be exercised. The observations made by it may be both written and (if need were) printed here likewise; several colonies may thus inhabit it, having their children born and bred up without the knowledge of land, who could not choose but be amazed with strange conceits upon the discovery of this upper world." The bishop adds: "I am not able to judge what other advantages there may be suggested, or whether experiments would fully answer to these notional conjectures." In 1774 a projector named Day lost his life in an experiment to descend in Plymouth Sound, with a vessel of about fifty tons burden, which he thought he could have caused to rise after a lapse of several hours. A long account of this failure was published. The machine by Bushnell, of Connecticut in 1771-5, for submarine navigation, was very successful; his vessel was propelled by screws. Mr. Babbage long since laid down a plan of a vessel for submarine navigation, in which he proposed to use oxygen, condensed in store vessels, to replenish the air, and to absorb the carbonic acid produced by respiration, either by cream of lime, or by a strong solution of ammonia. The principle of Payerne's diving-bell is the production of pure air fit for the respiration of man, and for supporting flame without communication with the external air. Deane's diving apparatus has been much used in submarine descents for the purpose of exploring various wrecks. In 1834, equipped in his diving dress, Deane descended by the ladder from the *Mary*, in seventy-two feet depth of water, to the wreck of the *Royal George*, the condition of which he represented, and slung and sent up one of the vessel's brass guns, a twenty-four pounder; by the same means six other of her guns were removed. Deane likewise attended Walker and Burgess, the engineers, and frequently descended to the foundations of old Blackfriars Bridge, and examined the work in progress. Heinke's diving apparatus was employed in removing the foundations of old Westminster Bridge, for five years, without any accident.

In the year 1838 the diving-bell became the paramount attraction of the Polytechnic Institution in Regent Street. It is constructed of cast iron, weighs three tons, is five feet in height, and five feet four inches in diameter at the mouth. It is lighted by twelve openings, of thick plate-glass, secured by brass frames to the bell. This is suspended by a massive chain to a large swing crane, with powerful crab, the windlass of which is grooved spirally; the chain passes over four times into a well beneath, and to it are suspended the compensation weights, which, by acting upon the spiral shaft, accurately counterpoise the bell at all depths. It is supplied by two powerful pumps, of 8-inch cylinder, with air conveyed by leather hose lined with caoutchouc cloth, and fitted inside with spiral wire. Nearly round the inside of the bell extends the seat; and on the side is affixed a knocker, under which is painted—"More air: knock once. Less air: knock twice. Pull up: knock three times." Provision is made for adding weight to the bell; and outside six massive vertical straps meet on the crown in a double ring, by which the bell is suspended from the crane. The four or five divers (visitors) having taken their seats, the air is pumped through the hose screwed into the crown, the bell is moved over the tank of water by the crane, let down within two feet of the bottom, and then drawn up. Each person pays one shilling for the descent, which has been known to yield the sum of £1,000 in one year. The cost of the bell was about £400.

Sir George Head, in his popular "Home Tour," has well described a pair of operative divers, whom he saw in the Hull docks. Sir George was passing as the workmen were raising the diving-bell, when, as the bell was raised very slowly, he looked within it, by stooping, at the moment its side was above the gunwale of the lighter. The pair of divers had been under water two hours. Their sensations on going down (before a man was used to it) produced a feeling as if the ears were bursting; on the bell first dipping, they were in the habit of holding their noses, at the same time of breathing as gently as possible, and thus they prevented any disagreeable effect. "Had there been anything extraordinary to see below," says Sir George, "I should have asked permission to go down; but the water was by no means clear, and the muddy bottom of the docks was not a sufficient recompense for the disagreeable sensation. Two men descend at a time, and four pump the air into the bell through the leathern hose; the bell is nearly a square, or rather, an oblong vessel of cast iron, with the two bull's-eye lights at the top, which lights are fortified within by a lattice of strong iron wire, sufficient to resist an accidental blow of a crowbar or other casualty." Sir George concludes: "Notwithstanding the great improvements made in diving-bells since this invention, after all precautions, a man in a diving-bell is certainly in a state of awful dependence upon human aid; in case of the slightest accident to the air-pump, or even a single stitch of the leathern hose giving way, long before the ponderous vessel could be raised to the surface, life must be extinct." Nevertheless, Sir George had previously remarked, "the service cannot be formidable, as the extra pay is only one shilling per day."

MINING AND QUARRYING.—IX.

BY GEORGE GLADSTONE, F.C.S.

IRON.

MODE OF SMELTING ORE—THE FUEL—THE FLUX—TEMPERATURE OF THE FURNACE—DIFFERENT QUALITIES OF PIG-IRON—IRON FOUNDING.

In the present paper we shall describe the method by which the smelting of the ore is carried on.

As a preliminary step the furnace has first to be put into blast, a process occupying upon the old plan a fortnight to three weeks, but now somewhat reduced. The building must in any case be heated up very gradually, because a too sudden driving off of any moisture, and too rapid an expansion of the materials of which it is built, would weaken the whole edifice. The modern plan is to fill the hearth with wood, cover that with five or six tons of coke, and then alternate layers of limestone, coke, and a little ore, until the furnace is about one-third full. The wood is then kindled, and the fire gradually makes its way upwards. As soon as it has extended through the whole mass, more materials are thrown in, the quantity of ore being gradually increased, until the furnace is full. When the whole is incandescent, the blast is turned on gently for a day or two, and then to its full strength, when the "blowing in" is completed.

When regularly in blast, the charge consists of three articles only—the ore, the fuel, and the flux. No one rule can be laid down as to the proportions in which they should be used, because this depends upon a variety of considerations, the most important of which is naturally the per-centage of metal contained in the ore itself: one-eighth of flux, and three-eighths of fuel, to four-eighths of calcined ore may be taken as approximate proportions; but how greatly these vary may be illustrated by the fact that the red hæmatites scarcely need any flux at all. There is, however, one rule of uniform application; that the furnace must be kept full. The charge is thrown in through the door in the chimney, or into the hopper of a closed furnace, on a level with the gallery, relays of workmen being constantly employed in keeping up the supply both by day and night. The furnace is tapped by driving a crowbar through the tap-hole below the dam-plate at the bottom of the hearth, so as to remove the sand, when the molten iron runs out. Before the tapping the blast is stopped; and as soon as the liquid iron has ceased to flow the tap-hole is closed with some fresh sand, the blast is turned on again, and the smelting proceeds as before.

The fuel is now almost always applied in the form of coke. It is generally made on the spot, and for this purpose the coal employed should be as free as possible from sulphur, and should leave but little ash. The cokes made from the bituminous coals of the north of England contain on an average about 0·60 per cent. of sulphur, some portion having already been volatilised and driven off in the process of coking. In the neighbourhood of Swansea anthracite coal is used in some works instead of coke. It has the advantage of being very free from sulphur, but it is difficult to work with, as it will not burn except at a very intense heat, often exceeding even that of a blast-furnace. Some of the anthracites will indeed scarcely burn at all; they decrepitate and form a fine powder, which collects at the bottom and becomes a regular nuisance by choking up the furnace and impeding the draught. For these reasons anthracite is but little used in this country, though in the United States it is the favourite coal for all such purposes, the American anthracite burning far more freely. In England bituminous coal is seldom used alone, though not unfrequently a small portion of it is mixed with the coke. In Scotland it is more common to smelt the black-band ironstones with the hard splint coal in its natural condition. In some few furnaces, especially where the best red hæmatites are smelted without intermixture of any inferior ores, charcoal is still used; a very superior iron is the result, which fetches a high price.

Limestone is almost universally employed as the flux. It seems to be providentially supplied for the purpose, the Carboniferous limestone which is associated with the coal and iron beds of that series being very pure, and therefore suitable for the smelter. The three articles, the ore, the fuel, and the flux, are therefore generally found in Nature in juxtaposition; but the ironmaster is really still further favoured, for the same geological formation supplies also the millstone grit, which is the best stone that can be found for building blast-furnaces, and the fire-clay from which the fire-bricks are made. The whole of the important articles required by the smelter, both for the fixed plant and the current work, may therefore be obtained upon the spot. At Dudley, the Silurian limestones lie in immediate contact with the coal and iron bearing strata; and the Silurian hills being favourably situated for working, they have supplied the flux for the neighbouring furnaces from time immemorial. Chalk, which is brought as ballast from the south of England, is often used to mix with other limestones in the Cleveland and Durham districts. After evaporating to dryness, the chalk and other limestones selected for the purpose contain from 96 to 98 per cent. of carbonate of lime.

In the best works all the three ingredients are subjected to analysis, to ascertain whether they contain any objectionable element, and to facilitate calculations as to the best proportions in which each should be used, so as to produce, without any waste of materials, those chemical reactions which are necessary to free the metallic iron. The heat of the furnace drives off the carbonic acid from the lime, which then combines with the silica and other earthy ingredients contained in the ore, forming a liquid slag, while the metal itself, being of greater specific gravity, finds its way down to the bottom of the furnace. The workman is principally guided by the appearance of the slag which issues from the cinder notch, as to whether the furnace is working satisfactorily; the colour, vitrification, and transparency of the slag when cooled being some indication of the character of the iron which is being produced. So slight a change of circumstances will affect the quality of the metal, that pigs yielded by the same tapping will prove to be of two, and sometimes even of three, different qualities.

It is impossible to ascertain the temperature to which the interior of a blast-furnace is raised, but as the melting-point of ordinary pig-iron is somewhere about 2500° Fahrenheit, it must at least approach very nearly to that figure. The heat of the gases which pass off by the chimney have been roughly estimated at about 1700° Fahr. immediately above the top of the charge; and it is evident that the greatest heat must be in the lower part of the furnace, because the upper portion is being constantly cooled by the addition of fresh material. Notwithstanding the intense heat, a well-constructed blast-furnace will remain in good workable condition for several years. Some parts, however, are apt to get out of order; and the twyers, in particular, should be well attended to, as a derangement of them may readily lead to serious consequences. Cases of explosion have been known, when all the molten metal has been blown out of the hearth because the nozzles of the twyers had become leaky, and the water supplied to keep them cool found its way into the furnace itself. Accidents similar in character have also arisen from the workman omitting to tap the furnace at the proper time, and so allowing the metal to accumulate above the level of the twyers.

Four qualities of pig-iron have been spoken of; they are distinguished commercially by consecutive numbers, but are often spoken of as *dark grey*, *bright grey*, *mottled*, and *white*. They are also separated by some into two classes, *foundry* and *forge* pigs; the founders again subdividing the former according to a classification of their own. Nos. 1, 2, and 3 are foundry pigs, the white being quite unsuitable for this purpose. As a rule the lower numbers are the most valuable, white iron being indicative rather of some derangement in the working of the furnace. No. 1 generally comes off first when a furnace in good working order is tapped, and then No. 2, and sometimes even No. 3. It contains more carbon than the lower numbers, which is advantageous in some of the subsequent processes for converting it into malleable iron. No. 2, the bright grey, is the best for making castings. No. 3 is a mixture of grey and white iron; the last, No. 4, is extremely hard, and at the same time very brittle. The presence of sulphur and phosphorus tend to produce the objectionable qualities of No. 4; at other times this iron is the result of some derangement in the working of the furnace; there are, however, white irons of excellent quality which will take the earlier numbers, such as that due to the presence of manganese, which is highly prized.

Pig-iron always contains more or less carbon in combination, which may amount to as much as 5 per cent., forming a carbide of iron. This will have to be referred to more particularly in describing the puddling processes. There is generally, also, silica present, which is objectionable on two grounds: first, that of weakening the strength of the iron; second, of causing waste of material and additional labour in puddling. Iron made by cold blast is comparatively free from this ingredient, the heat of the furnace being less intense than when the hot blast is used. Manganese has already been mentioned as being beneficial in its character; this is particularly the case when there is an excessive quantity of phosphorus, as it causes the almost entire removal of the latter during puddling. A highly manganiferous pig without phosphorus is puddled with difficulty; but when the latter is also present, the operation proceeds satisfactorily without more than the usual waste. Phosphorus alone, even when there is only 0·5 per cent. in bar-iron, renders it *cold short* or brittle. Sulphur is still more objectionable, a mere trace rendering the iron *hot short* or incapable of being worked at a red heat under the hammer. As all coal contains some little of this ingredient, and it is only partially volatilised in coking, some small proportion of it is sure to find its way into the iron, [illegible] to prevent it. If the [illegible] times mixed with it in the coking ovens, in order to convert the sulphide of iron into a sodium salt which can be more easily got rid of; or else an additional quantity of lime is used in the blast-furnace for the purpose of taking up some of the sulphur.

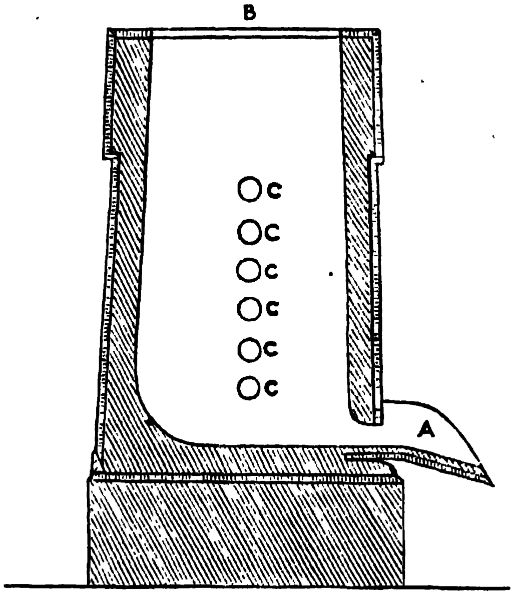


Fig. 6.

Foundry pigs have already been mentioned. Before passing to the elaborate processes required to make iron malleable, it will be well to describe the use to which pig-iron, as such, is put. The articles made are commonly called "castings," and they are the work of the founder. The plan adopted in their manufacture is simply to re-melt just so much of the pig-iron as may be wanted at the time, and pour the liquid metal into the moulds prepared for it of the form required. The process, apparently very simple, requires, however, a considerable amount of nicety, and workmen of experience.

A foundry consists of a large shed, with a deep bed of sand for its floor; two or three cupola furnaces of different dimensions for melting the iron, provided with twyers and a blowing engine; travelling cranes for moving pots of the molten iron to other parts of the premises; and a large collection of models and materials for making the moulds. We will take the last of these first, so as to follow the order of the process. The moulds are made of sand, a material being required to which the iron as it cools will not adhere. Moulding sand has, however, to be specially prepared in order to make it bind properly. It should be fine and even in quality, and should consist principally of silica with the addition of a little alumina. Loam consists principally of alumina, with a little silica. It will, therefore, be readily seen that by a mixture of pure sand with loam the relative proportions of these two ingredients can be adjusted. It can be still further improved, however, by mixing with it some coke-dust ground fine. This constitutes moulding sand, and is the article of which the floor of the foundry is made. The relative proportions of these ingredients is varied somewhat, according to the nature of the articles to be made; for some purposes the moulds are made altogether of loam, which have to be carefully dried in an oven before they are used.

The making of the moulds, especially when the casting is to be either a complicated or an elegant one, requires much care and nicety, and often artistic skill. They are made in frames without top or bottom, called "flasks;" these consist of sheets of iron firmly bolted together, the lower frame having ears on its upper edge exactly corresponding with others on the lower edge of the upper frame, so that the two frames can be united with precision. The frames are placed on the floor, and some of the old sand of the floor is shovelled into one of them and rammed down firm, a little fresh sand being employed to finish off with. The model already made in wood or metal is pressed into this, and then the other frame is placed upon it and filled in with sand after the same manner. On being lifted off again, and the model taken out, we have then the impression of the two sides of the model, one in either frame, and exactly corresponding; wherever necessary the mould has to be trimmed up, and it is then dusted over with a little finely powdered charcoal. The moulder has then to make a channel through the sand for the admission of the molten iron, and also some exits for the air and gases, so that in no part of it shall the air be shut in, or the iron will not be able to penetrate, and the casting would be imperfect. These perforations are made with wires; in large castings and complicated patterns they have to be numerous, besides two or more openings for the admission of the iron, so that it may be poured in at each simultaneously.

The frames being now prepared the upper one is replaced, and the two are firmly fixed together. The iron is then poured in, and when sufficiently cool, the upper frame is removed and the casting lifted out. Adhering to the casting will be [illegible] with a hammer; and when quite cold the [illegible] and other roughnesses are trimmed up with chisels or files. The metal having slightly contracted, the casting is generally removed without much injury to the mould, the latter being made somewhat larger than the ironwork is intended to be, so that when it has cooled down it shall be of the exact dimensions required; for this purpose the scale of the founder has to be increased by an eighth of an inch in a foot. There are many articles of very large consumption made of cast iron, such as water-pipes, wheels for machinery, some sorts of nails, railway chairs, etc., in making the moulds for which various mechanical appliances have been contrived for reducing, and almost superseding, the manual labour; these appliances not only ensure great uniformity in size and form, but effect at the same time a considerable saving of expense.

The iron is usually melted in a small cupola furnace of the form shown in Fig. 6. It is made of iron plates, lined with sand mixed with a little clay. While the melting is going forward, the spout A is stopped up with some moist clay; the charge is thrown in at the top, B; and the twyers for supplying the blast, which is generally driven by a fan, are inserted in whichever of the openings C, C, C may be desired, the others being closed up with iron plates. As the quantity of iron to be melted varies with the size of the casting to be made, the twyers are movable, as the nozzles must be placed just above the level of the molten iron. The furnace is lighted with some pieces of wood, and then filled up to the throat with coke, the spout being left open during the warming. The latter is then closed, the blast is turned on, and some pig-iron broken in small pieces, together with bits of waste metal from previous castings, are thrown in on the top of the burning coke; as the charge sinks down more coke and iron is added until the required weight of metal is reached. When the furnace is tapped the metal is received into an iron pot with a lip, which is carried either by hand or by a travelling crane to the mould, from which the iron is poured in. The floor of the foundry generally contains some large pits, in which the moulds for large castings are sunk, so as to avoid the inconvenience of having to pour in the metal at a considerable elevation.

During the melting there is some little loss of iron, as the metal will combine with any earthy matter that the fuel may contain, forming a slag which floats on the surface; pig-iron which contains silica will, however, be improved in quality by the process, of course at the expense of quantity, the silica being then converted into a silicate of iron, which will also separate itself from the metal.

THE STEAM-ENGINE.—XI.

By J. M. Wigner, B.A.

AGRICULTURAL ENGINES, PORTABLE AND FIXED—TRACTION-ENGINES—STEAM-ROLLERS—PUMPING ENGINES—STEAM-HAMMER—STEAM FIRE-ENGINES.

Thus far we have inquired into the general principles on which the steam-engine is based, and also explained the construction and action of the more common forms of stationary engines, and of those employed in propelling steam-ships. In the present paper we propose to explain the construction of those which are commonly employed for agricultural or other special purposes; and in our next and concluding paper we shall treat of the locomotive and its construction.

The steam-engine has of late been very largely employed in many agricultural operations, as, for instance, in driving threshing machines, chaff-cutters, and various other machines that are in almost constant use on the farm. Besides this, the system of ploughing and cultivating the land by means of steam power has been rapidly spreading, especially on large estates. The result of all this has been that many makers have directed their special attention to the manufacture of engines for these purposes. The main requirements in an engine of this kind are simplicity of construction, so that it may be worked with safety by the more intelligent class of farm labourers, and may not easily get out of repair; it should also be compact in form, and either portable, or so made as easily to be fixed, and, if required, to be moved again.

These engines may be divided into two main classes: those which are mounted upon wheels so as to be easily drawn about from place to place, and those which are fixed; these latter being frequently known as "independent" engines. Different makers vary considerably in details, but in their main features most of these engines closely resemble one another. They generally consist of a boiler with internal fire-box and horizontal tubes similar to those employed in locomotives. The chimney is made rather long, so as to create a good draught; but, as this would render it rather inconvenient in moving, it is jointed, so that when travelling it lies above the boiler on a special support provided for it. The cylinder is usually horizontal, and is firmly bolted to the upper part of the boiler, which is thus made to serve as a support to which all the various parts of the engine are secured. Some makers, instead of this, place a large saddle frame across the boiler, to which they fix the various fittings, and this plan seems to be gaining favour.

The connecting-rod is fixed to the piston-rod very much in the same way as in the horizontal engine already described, and thus turns the crank of a shaft which is placed across the top of the boiler a little way behind the chimney. This shaft is often so made that the fly-wheel may be fixed on either end, and the machinery is driven by a strap passing round this, or else round a special driving pulley suitably placed on the shaft.

The engine is usually fed from a large tub or other vessel placed by its side, into which a flexible suction hose is made to dip. The feed-pump is fixed to the side of the boiler, and is worked by means of an eccentric on the driving shaft. The boiler itself is well covered with felt and wood lagging, for the double purpose of economising the heat as much as possible, and also of avoiding risk of burns by coming into contact with it.

As will be seen, all the various parts of the engine are very securely bolted to the boiler or frame, and thus there is little fear of the joints working loose by the jarring and shaking incurred in moving it from place to place. The wheels are usually made with iron spokes, and a broad flange, to guard against their sinking too deep into the soft ground, over which they often have to travel. When the engine is drawn into place the shafts are removed, and wedge-shaped blocks placed under the wheels to keep the engine from shifting its position through the oscillation.

Independent engines are made very similar to this, with the exception of the wheels. The loose ash-tray under the fire-box is, of course, inadmissible, as the engine has to rest on this as a support; the fire-box, therefore, is made a little deeper, so that there may be room for the ashes under the furnace-bars. A firm pillar or iron pedestal is placed under the funnel end, and thus the engine may be placed upon two stone slabs or similar bearings without any masonry being required to fix it in position. Sometimes the support at the fore-end is so arranged as to serve as a hot-water tank, from which the boiler is fed, but this is not often the case.

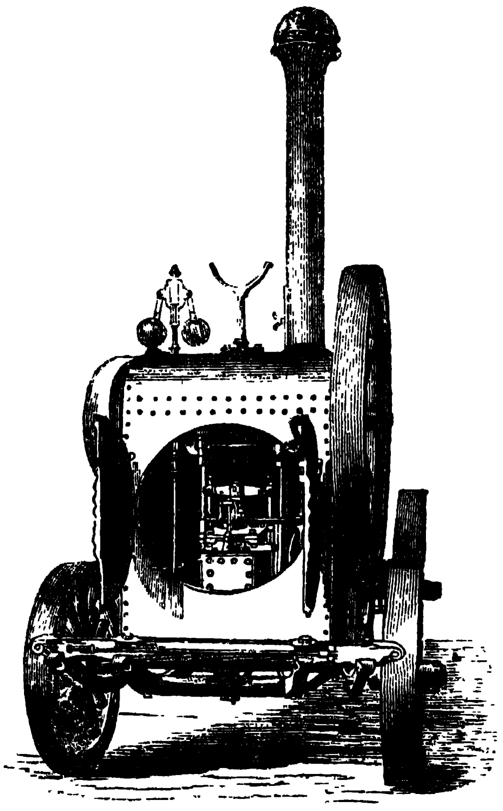


Fig. 44.

Some makers place the cylinder and the pipes leading to and from it inside the boiler or steam-chamber over the fire-box. In this way they are entirely protected, and during frosty or snowy weather there is a great benefit in this plan, as priming and condensation of the steam are thereby avoided, while at the same time there is a considerable saving in fuel. The machinery is likewise better protected from accidental injury and from rust.

In the engines made by Messrs. Tuxford, one of which is represented in Fig. 44, the funnel is placed at the same end of the engine as the furnace, and all the mechanism is contained in an iron case at the other end of the boiler, so as to be entirely under cover. In these engines the cylinders are vertical instead of horizontal, as in most other agricultural engines, and doors are provided in the end of the case, so that the machinery may easily be got at to oil or clean it when necessary. This form of engine has met with much approval; and as they usually have to work in the open air, the protection thus afforded to the machinery causes it to last much longer than it otherwise would. The gauge-cocks, safety-valve, and other fittings are the same here as in the engines already described. The chimney is provided with a spark-trap to prevent the escape of red-hot cinders or sparks; and as these engines are often used to drive threshing machines in stack-yards or similar places, this protection is very necessary.

An engine of this description is sometimes used for steam ploughing and cultivation. When this is the case, it is made to impart motion to a large drum, so constructed as to turn at pleasure in either direction. A wire rope is then made to pass along each side of the field, suitable rollers and pulleys being provided to diminish its friction as far as possible. These pulleys are fixed to anchors, which are moved from time to time as the plough travels from side to side of the field. Several ploughshares are usually fixed side by side on one frame, so that some six or seven furrows are ploughed at the same time; and a second set of shares is also fixed in the frame, which act when it travels back again to the side of the field from which it started. In this way the work is very rapidly accomplished. A rope is fixed to each end of this compound plough, and by this it is thus alternately drawn from side to side of the field, the anchors and pulleys being successively moved nearer and nearer the side on which the engine is placed. Another plan is to fix the drum to the engine, and place this at one side of the field, and a pulley with its anchor at the other side; both engine and pulley are then gradually moved along from one end of the field to the other, the plough moving backwards and forwards between them till the whole is completed. A considerable drawback to this mode of cultivation is the expense of the rope, which is found to wear out very rapidly. Traction-engines have accordingly been tried, which travel across or round the field, drawing the various implements after them. These have not, however, answered so well as to come into very general use; the great difficulty at first arose from the engine-wheels sinking deeply into the ploughed land, but this has been overcome in a very remarkable manner. It is found that if the tire of the driving-wheel be covered with a thick layer of india-rubber, it accommodates itself to the surface over which it passes, and in this way acquires such a large bearing surface that the wheel scarcely sinks at all. At first we should imagine that tires of this sort would very rapidly wear out and become cut to pieces by the stones on the roads over which they pass; practice has, however, shown that this is not the case at all, and that they last a considerable time. In fact, the introduction of these india-rubber tires has been the greatest step yet taken towards the general employment of traction-engines for many purposes for which teams of horses are now used. "Road steamers," as they are called, fitted with these tiers, have, in the last year or two, been submitted to almost every test that could be devised, and have been found to work in a highly satisfactory manner, and many more are now being made both for home and foreign use.

Many traction-engines were formerly so constructed that they laid an endless railway for themselves, along which the wheels travelled. A series of wide bearing-plates were connected at the ends, and fixed to the driving-wheels in such a way that they were successively laid down for the wheels to pass over, and taken up again immediately afterwards, the whole arrangement being self-acting.

Most traction-engines are made with three wheels, the front one being made to turn in a pivot: this wheel can then be turned by means of the steering gear, and thus the course of the engine can be altered at pleasure. The various details have all been so well carried out in many road steamers now made, that they can be turned in a very narrow space and guided with the utmost precision. They have lately been employed for military purposes, such as drawing heavy guns and placing them in position, and for this too they have been found to answer well.

Occasionally engines are so constructed as to serve either as traction-engines or ordinary portable ones, and these are called combined engines. In this case there is in some convenient place a large driving-pulley round which a strap can be passed to drive any required machinery, and also an arrangement by which the driving-wheels may be thrown in or out of gear at pleasure. This may be accomplished by means of a pinion which is made to slide along a feathered axle, and thus can be made to engage in teeth fixed to the inner edge of the driving-wheels. The motion is, however, often imparted to the driving-wheels by means of an endless driving chain, which possesses this advantage, that the wheels may be fitted with springs, and thus will accommodate themselves to the irregularities of the road, and render the motion much more uniform. In this country there are many restrictions as to the use of traction-engines along public roads, especially in the neighbourhood of large towns; but now that they can be made so much more manageable and compact, these restrictions will not improbably be modified, and then we shall find their use greatly extended. In many engines of this class either driving-wheel may at pleasure be thrown out of gear, and by this means sharp corners may be turned with much greater ease.

Steam-rollers have of late years been somewhat extensively introduced into large towns for the sake of levelling roads that have been newly macadamised, and they ought to be much more generally adopted, as great inconvenience is caused by compelling this levelling work to be effected by the ordinary traffic. The steam-rollers employed are essentially heavy traction-engines with very broad driving-wheels, and so constructed as to travel at a small speed. The boiler is usually a vertical tubular one, and the surfaces of the wheels are covered with broad wearing-plates which can be renewed at pleasure. Reversing gear is provided, the action of which will be fully explained when treating of the locomotive, and thus the engine can be driven either backwards or forwards at pleasure. A wide steering-wheel is so placed in front that it rolls the space included between the two driving-wheels. By driving this over the newly-laid stones a few times the road is rendered thoroughly firm and even in a very short time, and lasts much longer; nearly all the wear of the stones against one another is likewise avoided. The roller is usually weighted with ballast, so as to bring its weight up to about twenty-five tons.

Another very important class of engines consists of those especially designed for pumping purposes. In many factories, breweries, etc., the water has often to be raised from a deep well, or forced into an elevated cistern; and for these and many similar purposes, pumps driven by steam-power are commonly employed. Besides this, in most large towns a supply of water is now provided and delivered by means of pipes to the various houses usually at a pressure sufficient to raise it to cisterns placed in the upper storeys. For this purpose very large pumping engines have to be erected, as the water has often to be conveyed from a considerable distance or raised from a deep boring. Two totally different kinds of pump have come into common use: in one, the water is raised by means of a plunger which moves up and down in a cylinder provided with suitable inlets and outlets; in the other variety, known as centrifugal pumps, a wheel fitted with curved spokes is made to revolve very rapidly inside a chamber which it just fits, and by this means a constant stream of water is maintained. These latter may be driven by any ordinary engine, but the former are usually constructed so as to be a part of the engine itself. In many large towns a beam-engine is employed, and the pump-rod is fixed on the same end of the beam as the connecting-rod, usually at a point about half-way between the centre and the end. In other cases the connecting-rod and fly-wheel are dispensed with, the piston being jointed to one end of the beam and the pump-rod to the other.

Another plan is to invert the cylinders, and thus let the piston-rod be connected directly to the plunger without the intervention of any beam or other mechanism; this form of engine is decidedly the most simple, and hence has been employed in several large water-works. The pumps are now very frequently made double-acting, so that the water is raised while the water-piston is moving up as well as when moving down, and by this means a larger amount of water is raised, and the action is rendered much more uniform. A large air-chamber is, however, nearly always connected with the main pipe just after it leaves the pump. As each stroke is made the air in the upper part of this is to a certain extent compressed, and thus prevents the sudden jar or shock which would otherwise be given to the water. The reaction of the air between the strokes of the piston keeps the column of water in the pipes in constant motion, and thus a steady uniform flow is produced; in this way the strain is much diminished, and the pump rendered more effective.

In pumping-engines that are fitted with a beam, if the strain is greater while the plunger is moving in one direction than it is during the return stroke, a counterpoise is usually affixed to the upper end of the plunger, of such a weight as to balance this discrepancy, and thus cause the work of the engine to be uniform. The power required in some of these engines may be easily seen when we remember that the average supply of water that has to be provided for a town is from twenty to thirty gallons per day for each individual inhabitant.

For use in factories and other places where a large amount of water has to be employed, pumps of a much simpler construction are often employed. In many of these the cylinder and the barrel of the pump are firmly secured to a solid bed, so as to be in one straight line; the piston is then fastened to one end of the piston-rod and the pump to the other, both engine and pump being made double-acting. In this way great simplicity is attained, there are but few moving and wearing parts, and the whole occupies but little space. Small pumps of this description, known as donkey feed-pumps, are very frequently used for feeding boilers, for which purpose they answer very well. When the feed-pump is driven from the large engine, this has often to be started or kept running slowly, only for the purpose of maintaining a sufficient supply of water in the boiler. This causes a great waste of power, and hence an independent feed-pump driven by a cylinder of its own is generally used for this purpose.

The steam-hammer is another very important adaptation of the engine, and is now employed in nearly all large metal-works and foundries. Its construction has, however, been already fully explained in the papers on "Applied Mechanics" Vol. I., p. 410), and a figure of it has been given there, so that we need not further explain it, but refer our readers to that description.

Steam cranes and travellers are now very commonly employed in all extensive building operations, but they call for little special notice here. The boiler in them is usually vertical, and the piston makes short and rapid strokes. In the crane great care is taken to have the different parts well balanced on the pivot about which the whole rotates, and the various handles for starting and reversing the engine are so arranged as to be well under control and easy of access.

Blowing engines are frequently constructed for use in mines so as to secure a continual supply of fresh air to the various workings, and also in many foundries to urge the combustion in the blast-furnaces, and thus produce sufficient heat to melt the iron. In some of these the current of air is produced by large blowing cylinders worked by the beam: in many other cases a large fan is set in revolution by the engine, and this produces the blast.

The only other special engine we can at present refer to is the steam fire-engine. This has been introduced somewhat recently, but is of the utmost importance, especially in our large and crowded towns, where a fire when it once breaks out spreads with such amazing rapidity. In an ordinary engine a considerable amount of time is occupied in heating the water in the boiler, and getting up sufficient pressure of steam to work the engine. This, however, would never answer with a fire-engine, as almost everything depends upon having it at work as soon as possible after the fire has broken out, and before it has had time to make much way. The engine must also be extremely portable. These objects have now been attained by several makers, and various public competitions and prizes have stimulated them all to do their best.

The boilers, as we have already explained, are made to contain a very small quantity of water, and this is distributed between various tubes in such a way that it is everywhere in very thin layers, and the arrangements are such that the steam can easily rise from the internal surfaces. The tubes in these boilers are short, and packed extremely close together; this, of course, renders them very liable to become furred, but they seldom require to be worked long at a time, and they are so arranged as to be easily exposed for the sake of cleaning when necessary. The cylinder is short, being usually about seven or eight inches long, and six or seven inches in diameter. The piston moves very rapidly, making about 150 or 160 strokes per minute, and the pump is fixed to the other end of the piston-rod. The pump is double-acting, and discharges the water into a large air-chamber, from which it passes to the delivery-pipe. Some makers give a longer stroke to the piston, but in the majority of cases the short stroke is preferred. These engines have frequently been got to work within twenty minutes or less of the time that the fire was lighted; so that if the fire be lighted as soon as the alarm is given, steam is frequently got up on the road, and the engine is then ready to work by the time it reaches the scene of the fire.

OBJECT DRAWING.—VI.

SHADING.

In order that the drawing of an object may resemble the original, it is necessary that not only the shape, but that the ever-varying appearances caused by the rays of light falling upon it, should be imitated in our representation.

It is not in this place intended to enter into the subject of the *projection* of shadows, which will be fully treated of in another part of this work; but as a simple broad shade assists in "bringing out" a sketch of a solid form, a few hints are given to guide the student in shading from models.

It cannot, however, be too strongly urged that no attempt at shading should be made until the outline has been examined in every way to test its correctness; for it must be borne in mind that *no amount of shading will make up for bad drawing*, whereas a bold and clear outline may, in most cases, be made independent of any shading at all.

Only *one* light must be used when shading from a model, and this is to be placed in the manner which will best bring out the form of the object, by throwing some portion of it into the shade.

Now, if one of the rectangular solids be placed near the opposite edge of the table, the candle or lamp being situated on the side at which you are sitting, and on your left hand, then the light will be prevented falling on the *right* side and back of the model, whilst the front and left side will be fully exposed to the rays: the back and right-hand side will then be in *shade*.

But, in addition to the solidity of the object keeping the light from falling on the sides which are not opposite to it, it also hinders the light from falling on the *table*, which, near the back and right side of the model, will be darker still. This darker portion is called the *shadow*.

The distinction, then, between these two terms is, that any part of an object which does not receive the rays of light is said to be *shaded;* but when this object prevents the light falling on another surface, the part of that second object or surface which is thus obscured is said to be in *shadow*.

It may be taken as a general rule that, when the object and the surface on which it stands are of the same original colour, *shadows are darker than shades*.

Rays of light falling upon any surface are reflected from it, according as the surface is more or less polished, and the reflection will be more or less intense as the reflecting surface is of a lighter or darker colour. Any surface, therefore, which is directed towards light, not only becomes itself illumined, but casts a certain amount of light on objects opposite to it. Thus, supposing a cube is placed so that the light may fall on one side, whilst the other is in shade; if a sheet of drawing-paper is held up at a little distance from the shaded side, so that the light may strike directly on it, the rays will be reflected, and the shaded side will be visibly lighter than it was before.

On this point, Mr. Butler Williams says: "Although all surfaces that receive light do not reflect back an equal quantity, yet all do so to some extent, and to a greater or less degree according as they are placed less or more obliquely with respect to the luminous body and to other surrounding objects. Were it not for reflected light, those objects or surfaces which are not directly illumined would be so totally immersed in shade as not to be seen—their exterior figure or outline only would be visible. If an object bounded by flat surfaces be relieved by a wall or other surface, and the light be supposed to proceed from the left, we may notice three prominent varieties of tint. The lightest will be on those surfaces most nearly opposed to, or facing the light; the second will be on the side of the object from which the direct rays of the light are interrupted by the substance of the object itself; the third will be the shadow cast by that object on a part of the surface facing the light, but of which part is deprived of the direct rays of light by the interposition of the object in relief.

"Now the shade on the side of the projecting object appears lighter than the shadow adjoining, because, from the adjacent surface of the wall, a certain portion of light is reflected; and the shadow is the darkest because there is no surface near from which any strong light can be reflected to the place it covers. Shadows appear darker when cast on a surface in bright light than when cast on a surface in a fainter light or in shade; and the contrast, in the first case, between the shade and the adjoining shadow is greater than in the latter case.

"Also, in the case of a shadow falling on a flat surface, that part of the shadow which is nearest to the object which causes it is darker than the parts more distant; the shadow becomes gradually less intense the farther it recedes from the object whereby it is produced."

As the application of the principles thus laid down will be shown in subsequent objects and groups, some attention will now be given to the manner in which shading is to be accomplished.

If the drawing be small, it will be sufficient to employ the pencil to shade it. For this purpose the B will be found the best for general shading, HB for the lighter shades, and BB for the darkest shadows.

The shading should not be done by rubbing the pencil up and down, but by clear lines, which must afterwards be softened by a pencil of a slightly lighter degree; but the lines should still remain visible, though not too distinctly: and, in order to obtain the crispness and brilliancy so necessary to the beauty of a drawing, the lines should from time to time be brought out, so that they may not be lost in the filling in.

These lines are called "hatchings," and though no absolutely universal rule can be given as to their direction, it will be found best in most cases that the *lines should follow the direction of the plane on which the shadow falls.* Thus, let us suppose it were required to shade a cube suspended against the wall, on a higher level than our eye, which is situated on the right side, whilst the light comes from a point above and on the left side of the object. It is clear that, under these circumstances, we should see the right side and bottom of the cube, both of which would be shaded, and that there would be a "cast shadow" on the wall.

The side of the cube should be shaded with vertical and the bottom with horizontal lines, whilst the shadow on the wall should again be done in vertical lines.

Curved surfaces should be shaded by lines which partake of the general curvature, and these may be crossed by others, but care must be taken that these hatchings do not cross each other at right angles, like the threads in a woven fabric; they should cross obliquely, so that the spaces between them may be lozenge or diamond shaped. None of the hatchings should be visible when the drawing is viewed from a short distance, but should form a uniform clear tint over the shaded surface.

The largest and darkest shadow should be laid on first, for if the opposite plan were adopted the learner would have difficulty in so graduating his tints that the darkest portions of the work should not become *too* dark and heavy. Still, it is to be understood that the shadows and shades are not any of them at first to be made as dark as they are intended subsequently to be, for the constant retouching which the work necessarily receives would thus make the whole too dark; whereas, by getting the shadows generally spread over the whole work, and then working on each in turn, the relation of one to the other is observed, and no one part looks faded whilst others may look fresh. It is, of course, necessary to avoid smearing the work, but this is easy with a certain amount of care.

The outline, too, will require touching up as the drawing proceeds, but it must be particularly observed that in reality there is *not a line round objects*, and that therefore the boundary line which is necessary in a drawing must not be hard and darker than other parts, which causes the drawing to appear as if it were intended to represent an object bound with a band of iron; still, the form must be clear and defined, and care must be taken that in the process of shading the outline may not become ragged.

Drawings of objects when of a large size should be executed in chalks. Those most generally used are "French Conté crayons," Nos. 1, 2, and 3, and white chalk—also sold in sticks. These are held in chalk-holders, called porte-crayons. In lieu of these, the crayon may be rolled spirally in a strip of drawing-paper, which has the great advantage of lightness; and, for economy's sake, the small pieces of chalk may be fixed in a quill.

To point these chalks a certain amount of practice is required. Having placed the larger end in the holder, scrape the other until it approaches a pointed form; then, turning it in the reverse way to that in which a pencil is held, holding it between the thumb and middle finger of the left hand, and supporting the end on the forefinger, cut *from* the point towards the body, gradually turning the chalk round between the fingers: by this means, with a sharp, broad knife, and a little care, a fine point may soon be obtained. For model drawing, *very* fine points are not generally required; therefore, when the point has once been made, it may be kept sharp enough for some time by a small file or piece of sandpaper, a strip of which may be glued on a piece of wood like a small razor-strop. The three numbers on the chalks represent different degrees—No. 1 being the hardest.

The outline is, in the first instance, to be drawn with sketching-charcoal. This should be properly pointed, and the sketch should be lightly made. If this be done, any parts which may be deemed incorrect can be dusted off with a cloth, clean handkerchief, or a piece of chamois leather. This must not, however, be done too often, as the surface of the paper would thus become roughened, and the grain or "tooth" destroyed, and this would seriously interfere with the manipulation of the chalk. In addition to this, the habit of constantly rubbing out encourages want of care in the sketching; and therefore do not labour under the delusion that your first outline need necessarily be "only a rough sketch," but aim at correctness from the beginning.

When the outline in charcoal is satisfactory, it is to be dusted out, so as to leave merely a slight trace—just enough to guide the eye and hand. The lines are then to be repeated with crayon No. 1.

As a rule, erasure of the chalk-lines ought not to be required, since all the corrections should have been made in the charcoal sketch. If, however, alteration be indispensable, the lines may be rubbed out with stale bread, either in its usual condition, or pinched between the fingers until it is kneaded into a paste. It must, however, be understood that the use of bread always more or less unfits the paper to receive the chalk, and thus causes the shading to become spotty; and, further, the frequent use of bread makes the paper become greasy. Vulcanised india-rubber will, in some degree, remove this, but, again, the surface of the paper will suffer, so that the old adage, "Prevention is better than cure," must be borne in mind, especially so since the cure is not an efficient one; and thus again the absolute necessity for care is impressed on the student.

The paper used when the model-drawing is to be executed in pencil should be a good, firm, white cartridge, or any other which is not hot-pressed. If the paper be too smooth, the pencil glides over it, and a level tint will not be obtained without much difficulty, whilst if it is too rough the drawing will be coarse and unsatisfactory.

Tinted crayon paper is used for chalk-drawing; it may be had at various prices; but a cheap kind is now sold for use in drawing-classes and schools of art, which will be found quite good enough for general purposes. The paper generally used is of a pale grey or dull slate-colour, or drab. The colour ought not to be too positive, but should serve as a middle tint between the white chalk and the palest tints in the shading.

If the drawing be executed on white paper, it will require a background, and thus much time is absorbed, to a certain extent, unprofitably; in fact, by far more work is required on white paper, for all the middle tints have to be worked in with the chalk, which is not the case with tinted paper, as already explained.

The general ground for the shading may be laid on either with a piece of soft wash-leather, or a leather or paper "stump."

The "stump" is an implement made of chamois leather or soft paper, closely rolled until it is about the thickness of your little finger; it is then pointed at each end.

The crayon to be used for stumping is No. 2, or, for very dark shadows, No. 3. It is to be very finely scraped, or it may be rubbed on sandpaper, or filed, so as to obtain an impalpable powder. A little of this powder is then placed on a piece of waste paper, and the point of the stump is dipped into and turned round in it, so that it may be charged with the chalk.

Before, however, you touch the drawing with the stump, it must be rubbed on another piece of paper, so that the chalk may be evenly distributed over it, and that there may not be too much upon it. The quantity required must, of course, depend on the depth of shade to be executed.

The stump is then to be passed *lightly* over the surface to be shaded. If the space be narrow, the point must be used; if wide, the stump should be held almost horizontally, so that the side of the implement may be used; and for spreading the chalk over larger surfaces, the piece of wash-leather may be used for the same purpose as the stump.

The touch must be light and free, so as to spread an even tint over the paper. If you rub hard, the shade will become dark and streaky, and, further, you will injure the surface of the paper.

One end of the stump is to be kept free from chalk, to be employed for smoothing and softening the work of the other. Should one part turn out spotty, the parts which are too light must be touched with the dark end of the stump, until a level appearance is obtained.

The lights are produced by means of white chalk, rubbed on with the paper-stump; but for the highest lights the white chalk is used directly to the drawing. You will find the white chalk by far more difficult to cut than the black, and the points break off very often. Both these difficulties may, however, be lessened by cutting the point flat like a chisel, and then drawing the lines with the sharp edge.

The shades and shadows being thus laid broadly in, the hatching is to be proceeded with according to the directions given in the previous remarks.

FARMING AND FARMING ECONOMY.—IV.

By Professor **Wrightson**, Royal Agricultural College, Cirencester.

ROTATION OF CROPS.

A ROTATION or orderly succession of crops has been adopted by all good farmers, and is to some extent enforced in agreements between landlords and tenants: the origin, uses, and modifications, therefore, of such "courses of cropping" becomes a fundamental agricultural study. When a nation becomes fixed in its habits, and the bounds of individual property become definite, the cultivator of the ground can no longer leave his exhausted field in search of untilled virgin soil. Such unoccupied soil no longer exists, population having increased and occupied it all. In such an economic condition, a rotation of crops soon declares itself to be absolutely essential. It is a matter of observation, at any time capable of proof, that a newly broken-up field will grow heavy crops of corn for a longer or a shorter period; that while the earlier crops are characterised by an almost undue luxuriance, successive harvests tame and reduce the land, and finally, if continued, impoverish it to such an extent as to render cultivation unprofitable. So soon as this takes place, cultivation will in all probability cease, and the land thus left will clothe itself with natural herbage, and "lay itself down" to pasture. So it may continue, until some change in the relative value of grass and corn-growing land, increase of population, or other cause, induces its owner to once more break it up. The once exhausted field will then appear to have renewed its strength, and again will be crowned with abundant harvests. Such is the most primitive and the most simple conception of a rotation of crops. It has been acted upon in this country in years gone by, and still obtains in countries where agriculture is backward.

Such a system, alike slovenly and injurious, has happily long ceased to exist here. The fallow, or period of rest, has been converted into an opportunity for clearing away weeds, and bringing the soil into a fine state of tilth. The Israelites were ordered to fallow their land every seven years; the Romans understood the working of fallows well, and introduced their system into this country. No longer allowed to lie peacefully under grass, the land was subjected to a rigorous course of cultivation and aëration, and it was thoroughly cleared and prepared for the reception of a corn-crop. The interval between these fallowing periods was usually three years--the basis of the three year's "shift," at one time the common rotation over almost the whole of England. Later in the history of agriculture, we find the interval increased according to the quality of the soil; some lands being able to produce three, and others four or even more crops before the fallow need again be resorted to. The benefit of a naked or bare fallow is by no means easily explained. By analogy, it was formerly elucidated by supposing that the land was by this means *rested*. The idea of land requiring "rest" is, however, only a poetical fiction. To be tired involves, of necessity, a nervous system, or, at least, some kind of vitality, whereas the soil is essentially unorganised and passive. While we recognise the necessity of a fallowing period, we must, then, abandon the notion of land requiring rest. It is a mere question of food-supply. Let the reader bear in mind the origin of all soils—namely, the disintegration of rocks—and let him also bear in mind that such disintegration is not yet complete in any soil; that the very presence of undigested and unchanged rocky fragments of the original rock is always to be found in soils, and he will have a key to the mystery of the benefits of fallowing.

The necessary constituents of plants contained by all soils exist, then, in two forms—one available, and the other not yet available. In the one form, atmospheric and other agencies have effected their reduction, solution, or freedom, and have rendered them capable of absorption by plants. In the other form, they exist as fragments of felspar, of quartz, of phosphatic nodules, indigestible and insoluble, and yet containing what at some future time will be food for plants. Let successive winters exert their influence on this last as yet unavailable inorganic matter, and it, too, will be weathered into something useful to growing vegetation—nay, the very action of growing vegetables assists in breaking it down, and thus ministers to the fertility of the soil. Now, by working a bare fallow with ploughs, harrows, and rollers, new surfaces are exposed to the air, and disintegration is accelerated; hence the advantage of summer fallowing, even without the aid of manure. To this may be added a certain small supply of nitrogen, obtained from the air during the period of fallow, through the agency of rain, and which will have a beneficial influence on the succeeding crop. Such must serve as a very brief explanation of the benefits of fallowing land; and when dressings of farm-yard manure and lime are added, we cease to wonder why a fallow should restore wasted fertility.

Rotations of crops such as are now in use have only been possible since the introduction of forage and root-crops, and at the present day they consist in judicious alternations of these crops. It is not our purpose to enter into the chemistry of rotations; such a course would involve a much more extended treatment of the subject than is at present possible. We must, then, take at least three propositions for granted: first, that the repeated growth and removal of crops from the land does exhaust it; secondly, that each species of plant, having special requirements, will, if continuously grown upon the same land, take from the soil certain constituents, leaving others not necessary for its welfare: and thirdly, that soil which may be in a certain state of exhaustion with reference to one plant, may yet be in a condition to feed another, and this for two reasons:—First, because such other plant may require a different degree or kind of nourishment from the soil, or may be capable of using more of the nitrogen contained in the air; secondly, because it may have a larger root-surface, and thus be enabled to feed where its less favoured predecessor failed; or it may occupy the ground for a longer period, and thus be able to abstract sufficient nutriment for its development. As an illustration of this last, take the case of wheat and barley—the first requiring ordinarily six months', while the second only needs four months' possession of the soil. From these considerations it is clear that a greater produce may be derived from land by an interchange of crops than by growing one species continuously. But this is not all. Farming economy usually requires the maintenance of live stock—the production of animal food as well as of grain. This necessarily gives rise to the growth of forage-crops and root-crops, for the purpose of providing both summer and winter keep. Such crops are consumed upon the land, or at the farm-buildings, and, with straw and the remains of imported foods consumed by animals, form the "manure-heap." Such crops, then, are returned to the soil; while wheat, barley, and other corn-crops are sold off the farm. They also, being for the most part broad-leaved, take nitrogen and carbon from the atmosphere, which eventually, as manure, find their way into the soil. Thus there is a difference between green-crops and forage or root-crops; the one acting as exhausters, and the latter as renewers of fertility to the soil. Judicious interchange of these two classes of plants gives us the many forms of rotations of crops now in use. Let it not, however, be imagined that forage and root-crops essentially differ from other crops in their nature, but only in their uses. Removed from the land, they would in many cases be as exhausting in their effects, and even more so than grain-crops; but consumed upon the land, they are the means of keeping up and adding to its fertility.

It will be well also to note some additional reasons why our root-crops are well calculated to take the place of the old-fashioned bare fallow. The objects of the bare fallow are twofold: it is a means both of cleaning and of renewing the fertility of the soil. Root-crops, since they are sown comparatively late in the spring, and even into summer, allow of the land being cleared previous to their being sown; and the adoption of wide drilling enables cultivation to be pursued, both by horse and hand hoes, throughout summer, and even into autumn. Again, such crops cannot be successfully cultivated without liberal applications of manure; and they are finally either consumed on the land or converted into land-manure. Hence the root-crops can be cultivated in harmony with the objects of bare fallowing, and with the following advantages over the older system:—More capital can be profitably occupied in farming; light lands are better able to support the succeeding corn-crop; more labour is employed; winter feeding of stock, and fresh meat throughout the year become possible; and the agricultural value of the land is increased.

Rotations of crops are constructed with a view to peculiarities of soil, climate, and markets, and their modification is almost endless. In giving a few examples of rotations, we shall select them with a view to illustrating those general principles which must be kept in view in framing them. Heavy soils and light soils, peaty and calcareous soils—each are specially adapted for certain crops. Heavy lands have been named "wheat and bean" soils; light lands have been termed "turnip and barley" soils; and these phrases indicate the general adaptability of each. Accordingly, we find the heavy soils have been for the most part devoted to corn-growing, while the light lands have been employed in the cultivation of roots and the winter grazing of sheep. The heaviest soils are not adapted to root cultivation, but are more benefited by summer or naked fallowing.

Previous to laying before our readers a few characteristic rotations, we must explain the term "fallow," which is used to denote that section of the farm set apart for the special purpose of being cleaned and renewed in fertility. This may be treated as a bare fallow, in which case it is repeatedly ploughed and worked, and finally sown with wheat early in the autumn; or it may be prepared and planted with roots, or a forage crop, in which case it is termed a root or green crop. Every rotation commences with some form of fallow, and a fallow is invariably succeeded with a grain-crop. Usually this grain-crop is seeded down with grass-seeds, planted among the young growing corn, which continue to exist in a subjective manner until after harvest, when they occupy the ground, becoming the crop for the succeeding year. In some rotations these "seeds"—*i.e.*, mixtures of clover and grass seeds—so occupy the land for one, and in others for two years, after which they are broken up for a corn-crop, which again may or may not be followed with a second corn-crop. Sometimes beans or peas take the place of the seeds, and prepare the land for a crop of wheat.

We have already mentioned the old three-course shift as having been at one time general throughout England. The course commenced with fallow, after which was wheat, followed by beans. This course is still pursued in some backward parts of the county. It will be seen to be essentially a clay-land rotation, and one altogether inconsistent with the maintenance of live stock. It, however, affords a good instance of the manner in which a rotation may be modified. The original fallow, wheat, and beans may be converted into—

$$\left.\begin{array}{l}\text{Half fallow }(a)\\ \text{Half swedes }(b)\end{array}\right\}:\text{ wheat }:\left\{\begin{array}{l}\text{Half beans }(a);\\ \text{Half seeds }(b);\end{array}\right.$$

or, at length, into a six-course, as follows:—

Fallow: wheat: beans: swedes: wheat: seeds.

Here we have one-third of the land in fallow, one-third in wheat, and one-third in beans and seeds. It is still suitable for clay soils, but is in accordance with modern requirements. A rotation similar to this obtains in some parts of Essex. From two crops and a fallow, we pass to three crops and a fallow—a course suitable for the same class of soils, but of better quality. Thus, in South Bucks and parts of Oxon the following course is said to be in vogue:—

Fallow: wheat: beans: clover, or peas.

Again, we find rotation for clay soils in which five crops are taken between the fallowing periods. Thus, upon the good clay soils of Holderness the following course has been in use:—

Fallow: wheat: clover: wheat: oats: beans.

On the Carse of Gowrie even a more exhausting rotation has been adopted, namely:—

Fallow: wheat: barley: clover: oats: beans: wheat.

In this case it must be borne in mind that the oat-stubbles are heavily dunged for wheat.

In examining such rotations, fallow, clover, and beans must all be looked upon as good preparations for grain-crops, especially for wheat, which will do well after any of them. They are, however, all deficient as means for providing food for live stock; and we close this review of clay-land rotations by briefly describing a plan submitted to the Royal Agricultural Society some years ago by Mr. Stace, of Sussex, which will be found in the fourth volume of the Society's "Journal." This was an attempt to reconcile the maintenance of his stock with a course of cropping suitable to clay soils. The difficulty in feeding stock upon a clay soil may be thus stated. The root-crop can neither be fed off in the winter upon the land, nor carted off the land in wet autumn weather, without injury to the soil. The land is trampled with sheep in the one case, and with horses in the other. This is the great difficulty in root cultivation upon strong land, and to obviate it Mr. Stace recommends a system in which summer feeding of sheep was substituted for winter grazing. Accordingly, he proposed to grow forage crops during summer, and to feed them off the land in time to sow it with wheat. The plan proposed by Mr. Stace was as follows:—

1st year.—Winter vetches consumed on the land in May and June; followed with swedes, turnips, and rape. The root-crop and rape fed off as early as possible in autumn.

2nd year.—Wheat; seeded half with trefoil, and half with clover.

3rd year. { Trefoil, mown early, and sown with turnips to be fed.
Clover mown and fed.

4th year.—Wheat.

5th year.—Winter beans, followed with winter vetches as above.

It will be observed that this rotation has many advantages. The land is stocked with sheep during summer and autumn, when treading will not injuriously affect the land. The tillage is concentrated upon the time of year when clay lands work easiest—namely, autumn, when wheat, beans, and winter vetches all demand attention. The soil also is occupied with crops suitable to its character. On the other hand, it may be objected that there is too much work thrown on to one season of the year, and that it will be impossible to carry out such a system of cropping unless with the aid of steam. Also, that however suitable such a course may be for land in the south, it would be impossible to take turnips after vetches, or to adopt such a system of "catch-crops" in the north. These are serious objections; but we would urge, first, that with steam much may be done; and, secondly, that although the whole of a farm could not, perhaps, be managed upon this principle, yet a portion of the land might be so cropped as to ensure summer food for sheep in the manner proposed by Mr. Stace.

Perhaps no rotation is better known or has been more widely used than the Norfolk four-course. It appears in every county, and during the last two years, farms cropped upon this system have received first prizes given in connection with the Royal Agricultural Society, both in Oxon and Shropshire. The Norfolk four-course is as follows:—

Roots: barley: seeds: wheat.

It has been objected to as being too short, and because both roots and seeds occur too frequently. The rotation has been modified by allowing the seeds to remain two years, thereby changing it into a five-course; also by planting a proportion of land with beans or peas after barley. The Northumberland rotation is similar to the above, and comprises the following crops:—

Roots: barley or wheat: seeds: seeds: oats.

The East Lothian rotation furnishes us with the following succession, in which potatoes play an important part:—

Roots: barley, or wheat: seeds: oats: potatoes: wheat.

On calcareous soils, leguminous plants, such as clovers, beans, peas, and vetches, usually form a conspicuous feature; on peaty soils, rape, kohl-rabi, and oats are widely cultivated; on light soils, we find turnips and barley in perfection; and upon strong or stiff soil, wheat, beans, mangel-wurzel, cabbages, and kohl-rabi give excellent results. Thus upon each class of soils we shall find rotations framed with the view of introducing the most suitable crops.

We have, in the foregoing remarks, recognised rotations as valuable. A slavish adherence to any one of them is, however, bad; and the intelligent farmer should be able to exercise his judgment in the cropping of any particular field, instead of being trammelled by vexatious restrictions. Thus, two white straw-crops can be successfully grown in succession upon the same land, as has been proved again and again, and in some cases it is a course to be commended. Clauses which forbid such a method of cropping may be properly stigmatised as meddling; for, as has been well observed, you can neither prevent bad farming, nor command good farming, by lease-clauses. The true method of securing good management is, by a liberal policy, to encourage tenants of intelligence, capital, and position, who may then be allowed to farm to the best of their abilities, with as few restrictions as to management as is consistent with the true interests of the landlord.

WEAPONS OF WAR.—XII.

BY AN OFFICER OF THE ROYAL ARTILLERY.

BALLISTIC INSTRUMENTS.

A BRIEF description of the instruments which have from time to time been invented to determine the velocity of projectiles is proposed to be the substance of this paper. To clear the subject a little, it will be necessary to explain some of the advantages which may arise from knowing at what rate projectiles are moving through the air. The greater velocity any projectile has (*cæteris paribus*), we get—(1) greater range; (2) flatter trajectory; (3) greater penetration and destructive effect; (4) greater accuracy of shooting; in fact, four points which are of the greatest importance in artillery or rifle practice.

The maintenance of the velocity of a projectile over a certain distance depends on the amount of resistance experienced by it from time to time in its passage through the air; the greater the resistance, the greater is the loss of velocity, and *vice versâ;* so that it becomes a problem of considerable interest to determine experimentally what the actual resistance is to differently shaped projectiles, when moving with different velocities. For instance, you might get a high velocity with a spherical ball, and yet it might be inferior for an extended range, on all the four points mentioned above, to an elongated projectile fired with a lower velocity out of the same gun, chiefly for two reasons: (1) the increased resistance it actually meets with in its passage through the air; (2) the decreased weight which renders it less able to overcome the resistance of the air. So that supposing the two projectiles were started at the same instant, the spherical projectile would go ahead for a short distance, but would soon be overtaken by the elongated projectile, and finally strike the ground at a much shorter distance from the starting-point.

Let us now proceed in the description of some of the most successful of the instruments which have been devised for measuring the velocity of projectiles.

The ballistic pendulum was the instrument which gave the most practical results before the discovery of electro-magnetism; and Dr. Hutton, Professor of Mathematics at the Royal Military Academy, Woolwich, made a series of experiments from 1775 to 1791, from which he deduced his law of the resistance of the air, which, although it fails for low velocities, yet for velocities above 1,300 feet-seconds gives a fair representation of what actually takes place for spherical shot. Considering the roughness of the instrument, it is remarkable that such good approximate results should have been obtained.

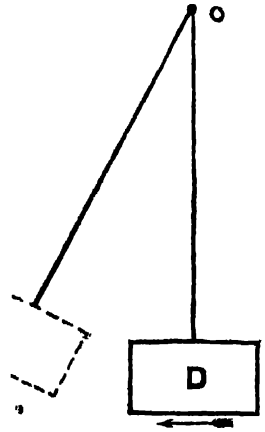


Fig. 1.

The ballistic pendulum (Fig. 1) consisted essentially of a receiver, D, commonly filled with sand, connected to the point of suspension, O, on which it could turn freely like an ordinary pendulum. The projectile was fired into this receiver, thus impressing the whole of its momentum to the pendulum, which recoiled through a certain angle varying with the velocity and weight of the projectile. This angle was carefully read off by means of a graduated arc attached to the instrument; whence, by a mathematical calculation, the velocity of the projectile at the point of impact was determined. The suppositions on which these calculations depended could never be *strictly correct;* hence the results obtained could not be regarded as anything better than an approximation to the truth. For instance, it supposes that during the penetration of the projectile into the sand the pendulum remained at rest, and also that the direction of the blow acted horizontally. There was also difficulty in striking the pendulum, so that there should be no vibration for impulse on the axis of suspension. As the distance from the gun increased, these difficulties became almost insurmountable. These defects, as well as the expense and unwieldy character of the machine, pointed to the desirability of contriving a simpler and more portable instrument to effect the same object.

Major Navez, of the Belgian service, was the first who succeeded practically in obtaining the velocity of projectiles by means of electricity. The instrument he devised was called the electro-ballistic pendulum, the pendulum being used to measure time instead of the force of the blow, as in the former instance.

This pendulum is capable of revolving about a horizontal axis through the point of suspension. A galvanic current circulates through an electro-magnet in the instrument, and through the screens, which are made of thin copper wire. When the current is circulating through the electro-magnet, the bob of the pendulum is raised up to its highest point, and kept there by magnetic attraction; and when the current is broken by the shot cutting the wire in the first screen, the electro-magnet becomes demagnetised, and the bob falls by its own weight. When the shot reaches the second screen, it cuts a wire through which another galvanic current is circulating, and consequently demagnetises a second electro-magnet which had been supporting a small weight. This weight in falling completes a third galvanic current, which sets in action a third electro-magnet, thus clamping a light index which had been travelling with the pendulum from its position of rest. The position of this index is read off on a graduated arc, and indicates the angle through which the pendulum had moved when the third galvanic stream was closed.

Another instrument called a "disjunctor" is used to break simultaneously the wires in the two screens, and the position of the index is read off as before to eliminate the errors of the falling weight, etc. etc., so that the difference between these angles represents, when converted into time, the actual interval which has elapsed during the passage of the shot from the first to the second screen. This being a certain measured distance, the actual velocity in feet-seconds is easily calculated.

Colonel Leurs introduced some modifications into this instrument, which have improved it considerably, making the observations obtained by it more reliable. He made use of two pendulums, one of which carries with it a registering needle, attached to a washer at the axis. The right-hand pendulum is provided with an arc of a circle, having the axis for its centre, upon which slides a steel strap and thumb-screw. Two springs are so arranged that when the right-hand pendulum falls the steel strap strikes the end of a lever, and releases the two springs, which at once close on the washer of the needle and fix the latter in position. The distance from the strap to the stem of the pendulum determines the position of the needle on the graduated arc, when the disjunctor is used. The difference between the length of this arc obtained with the disjunctor and the arc registered by the needle in actual trial, is the arc required. This modification of the instrument is usually called the "Navez-Leurs."

In the Navez and Navez-Leurs instruments, the time is measured by the arc passed over by a pendulum. This method of measurement is liable to *variation*, and a committee of reference appointed by the War Office has reported as follows:—"The time of describing any given arc is, of course, affected by friction; and in order to take this into account, the time of describing the same arc by a simple pendulum unaffected by friction is multiplied by a factor, the value of which is found by observing the instrumental measures which correspond to intervals of time which are known *à priori*, such as the time of a body falling freely through a given small space. It is found, however, that the *value* of this factor is *very sensibly different* for different parts of the arc of oscillation of the pendulum. Practically the factor is determined by means of falling weights with which the instrument is furnished, for a considerable arc, beginning a certain distance below the starting-point of the pendulum, then for another considerable arc beginning where the former ended, and similarly for a third; and in the conversion of an arc actually observed in the use of the instrument into time, the different values thus obtained are applied to the corresponding parts of the total arc described by the pendulum. On account of the very sensible variation of the factor, it may be doubted whether this mode of converting arc into time possesses a degree of exactness answering to the delivery of the instrumental indications. Thus, while indications nearly equal to each other may be compared by means of this instrument with great accuracy, we do not think that quite the same confidence can be placed in its determinations of *absolute velocity*, or of *relative velocity* when the difference between them is considerable. The case is somewhat similar to that of comparing different temperatures by means of a very sensitive thermometer, which, notwithstanding very sensible variations of bore, has been calibrated on the assumption that for very considerable portions of the interval which separates the standard points, the bore may be taken as uniform."

This error has been obviated in a chronograph invented by Captain Boulengé, also of the Belgian Artillery, in which the time is measured by the space passed over by a falling weight; while the employment of the electro-magnets is the same as in the Navez-Leurs. A long cylindrical rod is suspended vertically by an electro-magnet in connection with the first screen. Another electro-magnet in connection with the second screen suspends a shorter rod, which in falling strikes a trigger which releases a knife so as to mark the zinc tubes attached to the longer rod. These several operations require some definite time, which is allowed for by using a "disjunctor" under exactly the same conditions.

When the shot strikes the first screen the longer rod commences to fall; and when it strikes the second screen the shorter rod commences to fall, and releases a knife to cut the zinc on the longer rod.

The space through which the longer rod has fallen represents (when corrected for the disjunctor reading) the time the projectile has taken to traverse the distance between the two screens; and this distance being accurately measured, the velocity of the projectile is easily calculated.

All these instruments before described are only capable of measuring one velocity of a projectile; but it is possible *roughly* to measure the resistance of the air by using two different instruments, so as to get two velocities at two different points in the path of the projectile.

We are indebted to the Rev. F. Bashforth, B.D., Professor of Mathematics to the Advanced Class of Artillery Officers at Woolwich, for the accurate experimental investigation of the law of the resistance of the air to projectiles moving at a high velocity.

His chronograph consists essentially of a cylinder mounted vertically with a horizontal fly-wheel attached to it. Two markers attached to two different electro-magnets mark a uniform spiral on the revolving cylinder. One of the electro-magnets is connected with a galvanic battery which circulates through the screens, usually ten, which are placed at equal intervals apart. The other electro-magnet is connected with a galvanic battery, which is so arranged that a pendulum clock beating seconds interrupts the galvanic current once a second, and so moves the marker out of the uniform spiral, and thus gives a scale of time. When the circuit which circulates through the screens is broken, the marker in connection with the first electro-magnet is moved out of the uniform spiral, thus giving as many marks as there are screens. These intervals are carefully measured, and compared with the time scale; whence the velocity at the middle point of each space between the screens is obtained, and the actual resistance of the air at those velocities.

The *differential* character of this instrument makes the results obtained from it worthy of a high degree of credit, "since in this way each experiment supplies means of testing the accuracy of the results, which are *wholly wanting* when only two intervals of time are measured, and that by two different instruments."* The committee further report "that they do not think that any means existed before of recording a number of successive small intervals of time with the degree of precision and trustworthiness attained by Professor Bashforth's instrument." Professor Bashforth has also introduced a "gravity chronograph" for measuring velocities rapidly and accurately on a similar principle. In this instrument only one electro-magnet is used, which is connected with one galvanic current, and the marker, instead of tracing a spiral on the revolving cylinder, makes a small hole on the paper. The time, half a second, is measured by a weight falling freely through a space of 4·02 feet. When the weight commences to fall, the current is broken and a mark is made, then the projectile breaks the current when passing through the screens, usually three, thus giving three marks; and finally, when the weight reaches the bottom, the current is again broken, and a fifth mark is registered. Thus—

A (1) (2) (3) . B
. . . .

represents the records on the cylinder. A B, length of half-second; (1) to (2), time on the same scale the projectile takes to pass from first to second screen; (2) to (3), ditto from second to third screen. The second screen is not necessary for the observation of a velocity, but is only introduced as a check to see that the spaces are consistent. Knowing the distance between the first and third screens, the velocity is easily calculated by simple proportion, or can be read off by means of a slide-rule.

By the use of five screens, the resistance of the air can be more accurately determined with the gravity chronograph than by the use of two instruments, either of Boulengé or Navez-Leurs, although not with such thorough reliability as with the chronograph before described, on account of the possible slight variation in the velocity of the fly-wheel, during the half-second.

A chronoscope has also been contrived by Captain Andrew Noble, of Elswick, for measuring the velocity of projectiles in the bore of a gun. The principle is much the same as in the Bashforth chronograph, but the method of registering the breaks in the current is different. In the Noble chronoscope the mark is given by a spark on a blackened circular disc, made to revolve at a high velocity by means of toothed wheels—the mean velocity of which is measured by a stop-clock. This method of measuring time does not appear capable of so great accuracy as that adopted in the Bashforth chronograph, but it is said to give reliable results by those who have used it.

Experiments conducted with these two instruments form the basis of some very valuable knowledge in the science of gunnery, and will probably lead to still further investigations of the subject.

TECHNICAL DRAWING.—XLI.

DRAWING FOR STONEMASONS.

FREEHAND DRAWING FOR STONEMASONS.

In a previous lesson (Vol. I., page 47) we have said: "It is advisable that the student should be informed that *all* the drawing which is necessary for the artisan cannot be done with *rules and compasses*, but that some portion of the work must be done by free-hand."

These remarks apply with equal force to stonemasons. Surely, it cannot be right for a man to make up his mind that because a templet cut out of zinc, etc., is given him, his sole work in life is to place it against the end of the block of stone, scribe round it, and chip away until the block is the same shape all along—to work a plain surface to a block, to work accurate joints, or to set the stones according to the working drawings; although all such work, and very much more, are not only important, but absolutely indispensable to the mason. But the workman must remember that he is not a mere machine; that knowledge and intelligence are required in every branch; and that the more accurately the eye is educated to appreciate carved forms, the more readily will the hands execute the work. The manual skill of our stonemasons is unquestioned; the noble buildings daily rising up around us testify to this; and it is to urge on the British workman the necessity for increased mental culture and refinement in skilled labour that these lines are written. A mason may not have to design a moulding, a drawing or templet of which is furnished him by the architect or foreman of the works, but it cannot be doubted that he will execute it more readily and with greater accuracy if he understands the geometrical construction or appreciates the relation of one curve to another; and his knowledge will enable him to work with interest and intelligence, instead of by mere rule of thumb or, as it were, instinct. Besides this, the line which separates some branches of masonry from stone-carving is difficult to define—the one grows out of the other; and although every man should determine to do his best in his particular vocation, it is still his bounden duty to use every endeavour to raise himself, and this can only be done by earnest study and perseverance. To the young artisan this is particularly addressed, and he is urged to follow up the elementary course of studies here laid down; thus, as he advances in years, he will advance in knowledge, and instead of going to his work as a mere day-labourer, he will throw his spirit into his occupation, and it will become to him a labour of love.

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* *Vide* Report of Committee of Reference on Chronographs, published by War Office. Page 157.

The schools of art which, thanks to the Government Department of Science and Art, are now widely spread throughout the country, afford means of instruction of the highest character. The admirably-arranged course of studies adapted for each branch of practical art, the collections of casts, libraries, and, above all, the excellent teaching to be obtained, all offer opportunities not previously open to working men, and of which they are urged to avail themselves.

In order to economise space, Fig. 372 may be used by the learner as three separate studies, of which the easiest may be taken first. Draw the vertical line A B, and the oblique line C D on the *right* side, giving the general inclination and extent of the curve to be drawn.

Now set off between C and D the points E and F, and draw lines at right angles to C D. Make these equal to E H and F G, and trace the curve through D, G, and H to C.

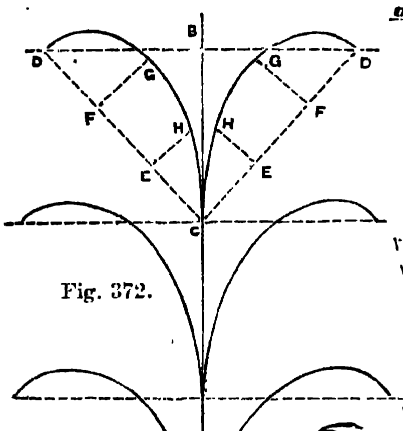

Fig. 372.

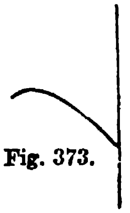
Fig. 373.

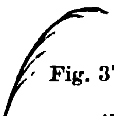
Fig. 374.

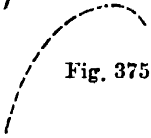
Fig. 375.

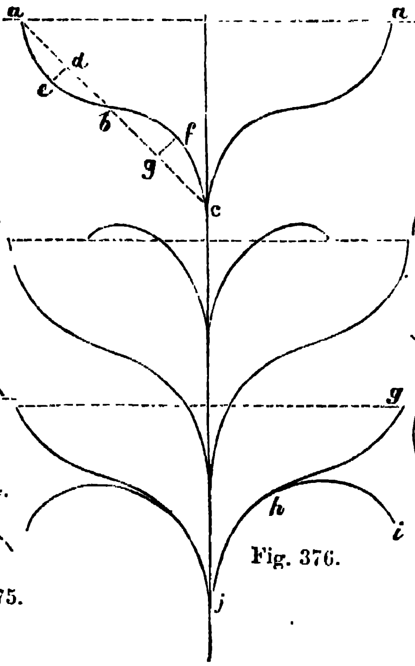

Fig. 376.

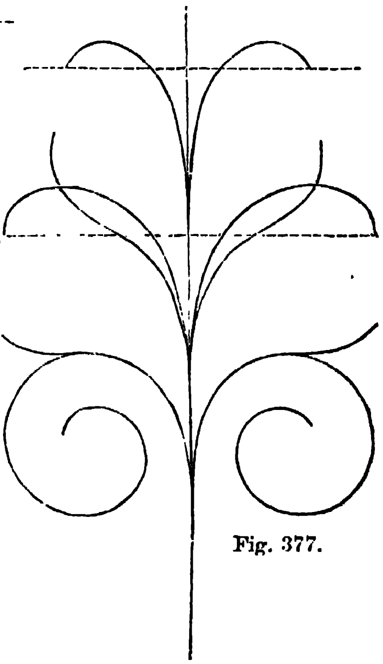
Fig. 377.

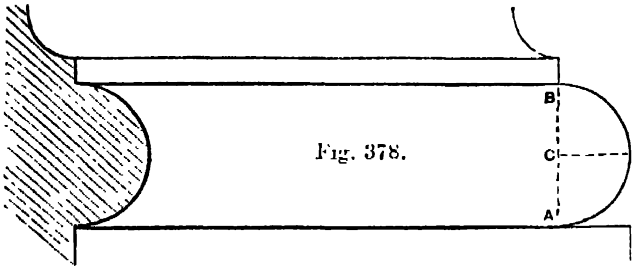

Fig. 378.

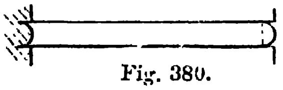
Fig. 380.

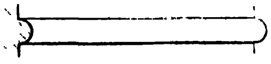
Fig. 379.

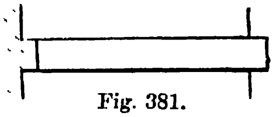
Fig. 381.

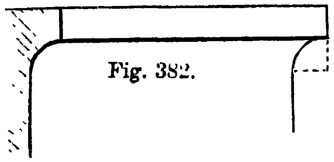
Fig. 382.

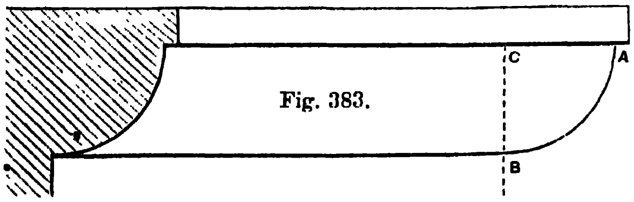

Fig. 383.

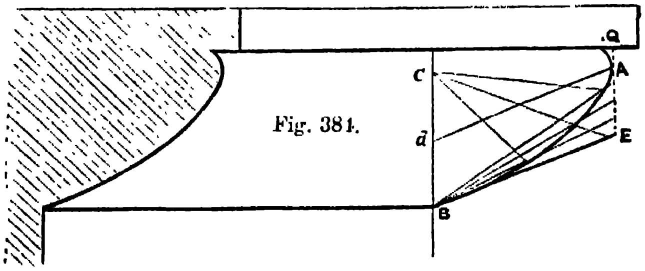

Fig. 384.

It must be pointed out that the curve must not spring suddenly or abruptly out of the perpendicular line, as shown in Fig. 373, but must merge so gradually into it that it shall become at last a portion of the straight line. This will require some little practice to accomplish, but as it is one of the most important points in ornamental drawing, attention is at once called to it.

The two lower curves on the same side may now be drawn, each a little larger than the one preceding it. The straight lines used in the first curve are, however, merely intended as leading-strings, and therefore, as soon as the smallest amount of power has been attained, they should be rejected, and the curve drawn without such extraneous aid.

Proceeding now to a further stage of the study, draw another vertical line, and draw the curves on the *left* side, which in the present study will be found rather more difficult to draw than those on the other; the hand should be placed rather higher up on the paper, and the pencil should be held rather longer than in the previous practice. It may here be well to mention that in free-hand drawing generally the pencil should be held as long, and the eye should be kept as far from the paper, as may be convenient. By these means freedom of hand and a just view of the form is obtained.

In sketching, these curves should be at first very lightly traced. They should not be made up of repeated scratches touching or crossing over each other, as in Fig. 374, but of small pieces, which in themselves form portions of the line to be drawn (Fig. 375).

Having thus practised the method of drawing simple curves inclined towards the right and left sides, the example may be copied as presented in the figure, the great object to be kept in view being that the curves must *balance* each other—that is, that the one on the right must be the exact counterpart of that on the left.

Draw the vertical line A B, and the horizontal D D crossing it; set off on this the distance to which the curves are to extend—viz., D, D—and on the perpendicular mark the point C. Now, whenever lines are to be balanced, the one on the left side should be the first drawn, for it will be clear that if the curve on the right side were sketched first, the hand would cover it whilst drawing the other, and this would add much to the difficulty of balancing the different parts. Horizontal lines, in order to regulate the heights of the curves, may be used in elementary practice; but after a while a few touches rapidly sketched across will be found sufficient, and all squaring of free-hand forms should be discarded.

Fig. 376.—The lines which form the subject of this study differ from the previous ones, in being each composed of two distinct curves.

It will be seen that the curve starting from *a* proceeds as far as *b*, and then turns in another direction. This peculiar bend requires much care, for the exact position of the point at which the change takes place materially alters the form. In order to afford some guide to the student, the line *a c* is drawn, and the change of direction in the curve takes place at the point *b* of this line.

As in the last subject, it is intended that the single curves should be practised before attempting to balance them.

Draw a vertical line, and a horizontal at its extremity; draw *a c* at the required inclination, and mark on it the point *b*.

Now divide *a b* and *b c* into equal parts, and draw the lines *d e* and *f g* at right angles to *a c*. Make *d e* and *f g* equal to the depth of the curve; then, commencing at *a*, trace the curve through *e*, *b*, *f*, to *c*.

Care must be taken that there be not a sudden bend at the juncture, but that the curves may flow gracefully and imperceptibly into each other.

Assuming, then, that the student has had some practice in drawing the separate curves as they appear on each side of the vertical line, he may then proceed to draw the complete subject, aided at first by the guide-lines, and subsequently rejecting them.

In the two lower curves the practice is advanced to a curve growing out of another. This is another important point in ornamental drawing, and has been referred to in relation to Fig. 372. It will be seen that, although the branch *i* springs from *h*, it does not project suddenly from the curve *g j*, but merges gracefully out of it; so that if the part of the curve *g h* were removed, the curve *j h i* would still be complete; and if the branch *h i* were taken away, the remaining curve, *g h j*, would not be interrupted.

Fig. 377.—In this study, the practice afforded in both the previous lessons is applied; the simple and compound curves being employed, and the branch carried round so as to form a simple scroll. The student is urged to copy the whole of the figures given in this lesson several times, as the practice they afford is of the utmost importance to him.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Mouldings.—When the face or edge of any work is wrought into long regular channels or projections, the sections of which form various curves or rounds, hollows, ogees, etc., it is said to be *moulded*, and each separate member is called a *moulding*.

Mouldings are divided into Grecian, Roman, and Gothic.

Grecian mouldings are formed of some of the curves known as conic sections, such as the ellipse or hyperbola, and sometimes even of a straight line in the form of a chamfer.

Roman mouldings have their sections composed of arcs of circles, and thus they are found the easier for elementary practice in drawing.

Fig. 378.—This is the simplest of all curved mouldings, and is called the *torus*. It is simply a semicircle described upon the vertical diameter, and is used in the bases of columns.

To draw the torus, let A B be the height of the member. Bisect A B in C, and with the radius C A describe the semicircle.

The torus, when very small, is called an *astragal* (Fig. 379), which projects; but it is termed a *bead* (Fig. 380) when it does not stand out beyond the surface. Several beadings placed together are termed *reedings*.

A *fillet* is a small flat face (Fig. 381) placed between mouldings to divide them.

A fillet is, in the bases of columns (as shown in Fig. 378), and at the top, as in Fig. 382, joined to a face or to the column itself by a small quarter-round hollow, called an *apophyge*. The word is originally Greek, and signifies "flight." English architects and builders generally term it the "scape" or "spring" of a column.

The method of drawing these is so very simple that it is not deemed necessary to do more than refer the student to the examples.

The *ovolo* (the name of which is derived from the Latin word *ovum*, "an egg") is a projecting mould, which in the Greek styles is a portion of a conic section, but which in the Roman is merely a portion of a circle—generally a quadrant—in which case it is called a "quarter-round" (Fig. 383).

To describe a Roman ovolo or quarter-round, let A be the upper extremity and B the lower. At B erect a perpendicular cutting a horizontal drawn from A in C; then, with radius C, describe the quadrant or quarter-round.

To describe a Grecian ovolo (Fig. 384), two tangents being given, as also their points of contact. Let A E and E B be the tangents; A and B the points of contact. Complete the parallelogram B *d* A E.

Produce B *d* to C, and make *d* C equal to *d* B; divide E A and A *d* each into the same number of equal parts. Through the points of division in A E draw lines to B, and from C draw lines through the points of division in A *d*. These lines intersecting those previously drawn, will give the required curve, which is a portion of an ellipse; the upper part A Q is a continuation of the same curve.

BRICK AND TILE MAKING.—III.

BY GILBERT R. REDGRAVE.

BRICKS AND TILES.

As brick-making is one of the oldest arts, so also are the appliances used therein amongst the most antiquated of any of our manufactures. Till within the last few years machinery, which was working such wonders in other branches of industry, was wholly ignored in the brick trade; and its introduction has been attended in many parts of the country with the most disgraceful and scandalous outrages and strikes. Near Manchester the bricklayers refused to use the machine-made bricks, and struck work; and the operatives in the brick-fields placed needles in the clay to maim those who had to use it. The machinery was frequently maliciously damaged, and the unburnt bricks trampled to pieces and destroyed wholesale.

Having in our two former articles treated of the preparation of terra-cotta, we now propose to glance at the processes employed in brick-making. In former treatises it has been usual to give numerous and accurate details of the mode of making bricks by the common old-fashioned method of hand moulding. We wish rather to treat of the manufacture as improved by the use of machinery and modern appliances, and as practised in the neighbourhood of most of our large towns at the present day. The two principal processes of producing machine-made bricks depend upon the state of the clay during the operation of moulding, and are known respectively as the dry or semi-dry and the plastic processes. Of these the dry or semi-dry is the more recent, and the plastic the older method. It will readily be understood that in dealing with plastic clay the material has, previous to its use, to be carefully tempered and prepared; and in the more perfect of the plastic brick-making machines we have accordingly apparatus for effecting this object. For the dry or semi-dry process all that is necessary is to reduce the clay to a tolerably fine state of division, which can be cheaply and readily done in an edge-runner or vertical mill; the production of bricks from this ground clay then merely depends upon the pressure which is applied to the dust in the moulds; for, as it is well known, nearly any homogeneous substance when ground to a fine powder can be consolidated to a surprising extent if exposed to great pressure. After this brief outline of the two chief modern systems, we may proceed to examine more minutely the details of each plan of working, beginning with the dry process.

The clay, as it comes from the pit or quarry, with little or no selection, and with no preparatory exposure to the influence of the weather, is conveyed to the edge-runners or other machinery used to pulverise it. We have mentioned the edge-runner, as this form of grinding is most frequently resorted to, owing to its cheapness and simplicity. This machine, as used in the neighbourhood of Leeds, has the bottom of the pan perforated with numerous small holes, through which the ground clay drops into the hoppers placed beneath it. Sometimes these mills have openings in the side of the pan, and in this case the contents are pushed by means of scrapers on to belts, which convey the materials to the sieves and elevators. Some firms use the disintegrator for grinding the clay; and this machine, though it takes a great deal of power, is an admirable and efficient mode of grinding. It may be briefly described as a series of cages of iron bars, which are made to revolve rapidly in alternately different directions. Into the centre cage the material to be ground is gradually introduced, and as it passes through from cage to cage it comes in contact with, and is carried round and round by the rapidly-moving bars, and dashed to pieces, escaping finally on the circumference of the outer cage in a finely divided state. A six-foot disintegrator will crush 180 tons of hard clay in ten hours, at a cost of little more than 6d. per ton, which is far below the cost of any other method of grinding we know of. For a common class of brick it is not necessary that the grinding should be very fine, though a tolerably uniform size for the grains of clay is of importance, and it is usual, therefore, to screen or sift the clay powder, which can be done for about a halfpenny per ton.

There are many dry-process machines before the public, and it would be invidious in such an article as this to single out any particular maker for special reference. The general principle arrived at in all cases is the same—namely, to provide a simple and expeditious plan of filling the moulds with the powder, applying the pressure, and of relieving the mould, and finally of delivering the moulded brick. A simple and useful form of the dry press is that which has a movable plate or table, which carries one or more moulds or dies. This table closes the orifice of a large hopper containing the ground clay; but, by a traversing motion which is imparted to it, the moulds which form recesses in it are constantly carried back to the hopper to be filled, and, on moving forwards, the level surface of the table again closes the hopper. The moulds having been thus filled, and brought under the pistons of the press which carry the plates or pallets to form the top, are then subjected to heavy pressure, either by means of steam, a hydraulic ram, a cam-wheel, or a stamping action, like that of the coining press. This pressure or blow may take effect only on the top of the mould, or on the bottom, or on both surfaces combined, and need, of course, only be instantaneous; though we are inclined to think that better work is done by a slow and gradually increasing weight, like that given by a cam, than a rapid blow such as is given by a screw-press. Having received the pressure, the brick is then forced out of the mould, either upwards to the level of the table, by causing the bottom of the mould to rise, or downwards by dropping the bottom plate with the newly-formed brick upon it. We like those machines best which lift the brick to the level of the table, and then, with a sliding arm, propel it to the edge of the table, in a convenient position for removal, while the next one is being pressed. Such machines are termed "self-delivering;" and in some a series of runners, covered with flannel, convey away the newly-formed bricks. Of course, in all the machines where the brick is made under pressure, the moulds have to be very strongly made of metal, and have also to be coned or sloped slightly outwards, in order to admit of the ready removal of the brick. Another matter which has to be attended to is the oiling of the mould. This should take place very frequently, if not after the withdrawal of every brick. The best machines are so arranged as to oil the mould each time with a brush or piston, which is in constant contact with oiled waste or wool. Machines of this kind are known as "self-lubricating."

It will readily be understood that as the clay for making pressed bricks in the way we have just described is used almost dry, they do not require to be "hacked" or stacked very long before they are ready for firing. Indeed, if the clay is used in too moist a state the water is squeezed out of it in the press, and its shape and appearance is spoiled. The consistency of the pressed bricks on leaving the mould is such that they can very readily be handled and built up in hacks to dry. We are convinced that there is no kind of kiln better adapted for drying and firing bricks than Hoffmann's; and we shall, therefore, in the first instance, describe this class of kiln. The upper surface of this kiln, on being roofed in, forms a most convenient drying floor for the bricks, and they may be wheeled up here from the presser, and stacked for a day or two so that they may become thoroughly dry.

The so-called "annular kiln" consists of a series of compartments surrounding a central chimney, and these compartments are so arranged that they can be connected together or separated from one another at pleasure by means of movable screens or partitions; and each compartment can in succession be placed in connection with, or cut off from the chimney by an arrangement of dampers. At the upper part of each compartment are numerous small orifices for the introduction of the fuel, and a door through the side wall of the kiln gives the means of filling and removing from each section the materials to be burnt. The kiln may with advantage consist of from ten to twenty compartments, each one of which would hold on an average 15,000 bricks; and the kiln, when in full work, may be filled and emptied at the rate of one compartment in every twenty-four hours. In a kiln of such a size as this the action is somewhat complicated and difficult to explain. We will endeavour as briefly as possible to indicate the mode of working a Hoffmann kiln with sixteen compartments. Starting from any one section, we will number them for reference from 1 to 16. If we, therefore, take No. 1, we shall have No. 16 on one side of it and No. 2 on the other. Supposing the kiln to be in full working order, No. 16 would be in progress of being filled with green or unburnt bricks, and from No. 1 they would be "drawing" or emptying the burnt bricks. The compartments 8 and 9 would be about in full firing, and the flue connecting compartment No. 15 and the chimney would be open, while Nos. 15 and 16 would be separated by means of a temporary screen of iron plates. The air to support the combustion would thus be entering the kiln through the door of section 1, and, passing through compartments 2, 3, 4, 5, and 6, it would assist in cooling them, and in return take up much of their waste heat. Through the holes in the roof of the 8th and 9th compartments the fireman would be introducing the fuel, and the heat passing from these two compartments would probably have made Nos. 10 and 11 nearly red hot, though no fuel had as yet been put into them. This heated air, in passing through 12, 13, 14, and 15, would be employed in driving off the moisture from the green bricks, the 15th compartment having only been filled on the previous day; the waste heat and steam would then escape from 15 through the flue into the chimney. If our readers have been able to follow us in this description, it will readily be seen that we have here the most favourable condition for economical working; for the heat given out by the brick in cooling is all carried forward and utilised in the firing, and the superfluous heat from the firing is made to "smoke" or drive off the moisture from the unburnt bricks. The mode of loading each compartment does not differ very much from an ordinary circular or flue kiln; it is only necessary in the lower part to leave free spaces among the bricks for the passage of the draught, and to arrange an open hole or fireplace beneath each of the feeding orifices in the top or roof of the compartment. These vertical fireplaces are kept exactly true by dropping a plummet through the opening, and it is customary to arrange a number of bricks in each one projecting slightly forward to serve as ledges on which the coal-slack or dust used as fuel may rest, instead of all falling in a lump to the bottom. In consequence of the admirable way in which the heat is utilised in these kilns, the quantity of fuel for a given number of bricks is extremely small—not more than from 3 to 5 cwt. of slack per thousand, while in the old form of kiln a consumption of 15 cwt. was not considered excessive.

The Hoffmann kiln is an almost perfect smoke-consumer—indeed, the presence of any smoke is at once a clear proof that some part of the operation is being mismanaged—and it does its work very uniformly, that is, the contents are very regularly and evenly fired. The chief objections which are brought forward against it are its great cost (from £3,000 to £4,000), and the fact that it necessitates a very large and constant make, as it cannot be stopped for a day or two when trade is slack, but must be kept continuously at work. Bricks made in the way we have described can be produced in a shorter time than those used from plastic clay, owing to the shorter time they take in drying. Thus, clay dug on Monday is made the same day into bricks, which would, under ordinary conditions, be dry enough on Tuesday to go into the kiln, and on being bricked up on Wednesday in a sixteen-compartment kiln they would be drawn on the following Saturday fortnight. The bricks made by the dry process, though generally truer and better in form than those made from plastic clay, lack the toughness and strength of the latter brick, and are readily broken by a smart blow with the trowel in setting, especially if they are slightly under-burnt. This seems to be owing to a want of due cohesion between the particles of clay, as the fracture of such bricks looks gritty, like stone, and moreover, their outer layer is often much harder than the interior.

The dry process lends itself very well to the preparation of the so-called concrete bricks, or bricks which rely for their consolidation upon the setting power of lime or cement, and not upon firing. In the neighbourhood of dwelling-houses the burning of bricks gives rise to many noxious gases and smells, not to mention the dense black smoke, and there is no doubt that sooner or later brick-fields will all be banished from the outskirts of inhabited districts. With this probability in view several manufacturers have set to work to discover the best way of making bricks from lime and sand or Portland cement and sand, which might in a few days after making become hard enough to use for building purposes; and owing to the vastly increased resistance of cement concrete made under pressure, it seems likely that this problem is on the eve of being solved. Thus, a mixture of one part of Portland cement and eight parts of sand gauged very stiff, or with a very small proportion of water, on being submitted to a pressure of twenty tons in a mould, set very rapidly, and in four or five days was ready for use. The economical aspect of this mode of manufacturing bricks depends upon the entire saving of fuel, the decreased amount of manipulation which is requisite, and the rapidity with which the article can be produced. All danger in the drying and firing are likewise avoided, and the bricks are all exactly uniform in weight and appearance. The defects of this system are the difficulty of mixing intimately the sand and the cement, the dinginess of the colour, and the weight of the resultant bricks. We think, however, that all these objections may be shortly overcome; and we hope to see concrete bricks before long in general use. It is obvious that the mode of dealing with the cement is the same as we have described for the semi-dry clay.

We may now consider the manufacture of bricks by the plastic process, which, we may add, is by far the most common of the two. For this purpose the clay is usually dug or "got" in the autumn, and allowed to remain in shallow heaps through the winter in order to "fall," though many manufacturers now look upon this as an exploded tradition of the trade. To temper it thoroughly, the clay is passed through horizontal rollers set to various gauges, which break up the hard lumps, and from the rollers it is passed into a pug-mill, where, under the action of knives or cutters, and with the addition of water, it is brought to a waxy consistency. In some machines the clay is forced out of the pug-mill in a stream of suitable size for cutting up into bricks, say ten inches by five inches. This stream of clay is conducted on a series of flannel-covered runners, and is from time to time cut up into slices three inches thick by means of wire cutters mounted in a frame, which can be made to move across and divide the clay into bricks. In other brick machines the clay from the pug-mill is passed into a cylinder, where it is subjected to considerable pressure, and squeezed out into a stream, which is then cut up into bricks by a wire traversing across the clay. In our next article we shall deal with other plastic processes, and some of the many varieties of brick kilns.

APPLIED MECHANICS.—XVII.

BY ROBERT STAWELL BALL, M.A.,
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MACHINERY USED IN SAWING TIMBER.

THE CIRCULAR SAW.

AMONG the most useful pieces of machinery used in the constructive arts the saw takes high rank. Without its aid it would be impossible, or nearly so, to cut up a tree or any large mass of timber into planks, or smaller pieces suitable for the purposes for which they may be required. But powerful as the saw may be in all its variations, from the tenon and keyhole saw to the long lithe blade worked by two sawyers in a pit, the work that is done by it, when set in action by manual labour, is slight when compared with that which is effected by it in its modified circular form, driven with great rapidity by mechanical appliances or by steam or water power.

The circular saw is a disc of thin steel, containing teeth on its circumference. The magnitude of the teeth depends very much upon the character of the wood which the saw is intended to be employed in cutting. They are generally very much larger than the teeth in the ordinary hand-saw. The circular saw is made to revolve with very great velocity, and the wood to be acted upon is brought against its circumference. In order to estimate the relation of the power which the saw exerts to its velocity, we shall enter into details with reference to the small circular saw represented in the next page (Fig. 1). What we have to say with reference to this saw we shall afterwards apply to large circular saws worked by means of steam-engines or water-mills.

C T is a heavy fly-wheel, containing a groove in its circumference for the reception of a band. A B is a treadle, which is worked by the foot. This treadle is mounted on a pivot at A, and at B the connecting-rod B P is attached to the crank C P: and the alternate motion of the treadle thus produces a rotatory motion of the wheel. The wheel must be tolerably heavy, because it is only during the down-stroke of the treadle that the force is communicated to the wheel, and therefore the inertia of the wheel must suffice to carry on the motion during the up-stroke. This arrangement is similar to that already mentioned in the lathe. The band which embraces the fly-wheel passes upwards to a pulley, O. This pulley is very much smaller than the fly-wheel. We shall suppose that the pulley has only one-tenth the diameter of the fly-wheel, and therefore the pulley will perform ten revolutions for each revolution of the wheel; on the same spindle which carries the pulley O the circular saw R is mounted. This saw therefore revolves with the pulley. The saw passes through a slit in the table upon which the block, S, to be sawn is placed. In order to examine the forces and velocities at the different points of this machine, we shall give dimensions to the different parts. Let A B, the treadle, be 2 feet long, and let the pressure be applied at the point D, midway between A and B. Let the crank, C P, be 2 inches long, the diameter of the fly-wheel 20 inches, the diameter of the pulley 2 inches, and the diameter of the circular saw 8 inches. We shall also suppose that the average pressure exerted by the foot upon the treadle is 30 pounds.

The point B oscillates through a space which is very nearly double the length of the crank C P. D moves through half the distance through which B moves, since A D is half of A B. Hence for each revolution of the wheel, the mean pressure of 30 pounds is applied through a distance of 2 inches, and therefore

$$30 \times \tfrac{1}{6} = 5$$

units of work are imparted to the wheel at each revolution.

The circular saw has in its circumference a length of

$$2 \times 8 \times \tfrac{22}{7} = 50 \text{ inches very nearly;}$$

and since a circular saw makes ten revolutions for each revolution of the fly-wheel, it follows that the edge of the saw will move through 500 inches while the power which gives motion to the machine has only moved through 2 inches. Hence the magnitude of the pressure which the margin of the saw is capable of exerting is

$$\tfrac{30}{250} = 0{\cdot}12 \text{ pounds, or nearly 2 oz.}$$

In the use of an ordinary hand-saw, the carpenter is conscious of exerting a force of several pounds in sawing a plank which can be cut just as easily and as rapidly by the use of a circular saw when the pressure of the acting parts of the saw only amounts to a few ounces. This difference is to be attributed to the great velocity with which the circular saw moves.

If we make the fly-wheel move round once in a second, the margin of the saw will travel 500 inches in a second, or about 2,500 feet in a minute. Let us suppose that the wood is cut at the rate of 1 foot per minute by the circular saw; then each revolution of the saw will have to cut about the two-hundredth part of an inch. The circumference of the saw contains, we shall suppose, fifty teeth; thus, since in one revolution the fifty teeth have only to cut the two-hundredth part of an inch, it follows that each tooth has only to take a cut of about one ten-thousandth part of an inch. Thus a very small force alone is necessary for the purpose of urging the teeth of the saw to their work. This force is in the case we have supposed about two ounces.

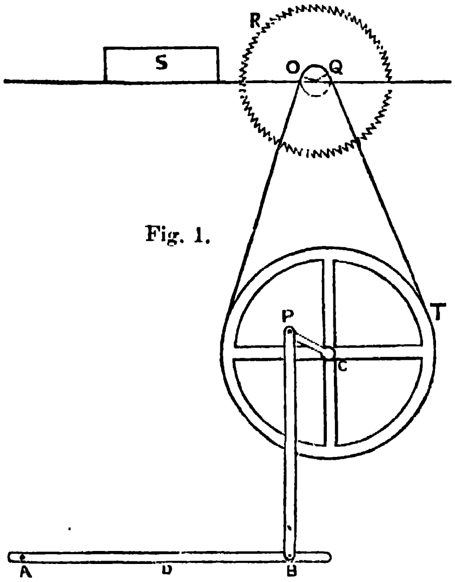


Fig. 1.

The advantage of working at a high speed, with small pressure and small cut, principally depends upon the smoothness and regularity with which the work proceeds under these circumstances. The circular saw itself becomes a sort of fly-wheel, and, by its high velocity, is able to move uniformly, notwithstanding the small changes in the resistance which are never absent from such a process as sawing. In sawing logs of wood into planks a series of parallel saws, which make several cuts simultaneously, are employed. The mode by which the saws are moved is very simple. The several blades are mounted in a frame which moves vertically upwards and downwards in guides. These saws are strained by wedges to the proper degree of tension. Pieces of wood of the exact width of the planks required are placed between each pair of saws, and the whole series is bound together tightly.

The mechanism which gives motion to the frame is shown in Fig. 2. C D is the frame, of which one saw, C D, is represented; A is the extremity of a shaft which carries the crank A B. This crank is attached to the end of the frame by the connecting-rod B C. Thus, as the shaft rotates, the frame oscillates backwards and forwards, and cuts the wood which is brought against it.

Special mechanism must be provided by which this log which is being sawn into planks shall be carried forwards during the operation. We shall first examine into the conditions which must be fulfilled by a perfect apparatus for administering the feed, and then we shall describe some of the different machines which are employed for the purpose. To saw uniformly, it is proper that each tooth should have to make a cut of the same depth, the amount of that depth depending upon the quality of the wood and the magnitude of the log which is being operated upon. The frame C D, and therefore the saw which it carries, do not move uniformly. When the extremity of the connecting-rod is at E, the saw is then at its highest point, and its velocity at that point vanishes. When the crank moves towards B, the velocity of the saw gradually increases, until the angle between the crank and the connecting-rod becomes a right angle; nearly at this point the velocity of the saw is a maximum. As the crank continues its revolution the velocity gradually diminishes, until it becomes zero at the bottom point, H. The crank then ascends through the semicircle H K E, and raises the frame, the saw ceasing to act during this part of the motion. Thus during half the time the machine is working the saw has ceased to act entirely, and during the remainder of the time the action is variable. These points determine the character of the motion which gives the feed. During the up-stroke of the saw the feed must evidently cease altogether; during the down-stroke the feed must be so applied that each tooth of the saw shall have the same cut to make. It is evident that this will not be the case if the feed be uniform during the down-stroke. The velocity of the middle teeth of the saw during the down-stroke is greater than the velocity of the extreme teeth; hence, if the velocity of feed were uniform, each of the extreme teeth would have to take a larger cut than the central teeth, and the work would not proceed with uniformity. The velocity of the feed during the down-stroke must be so regulated as to bear a constant proportion to the velocity of the saw at the same instant.

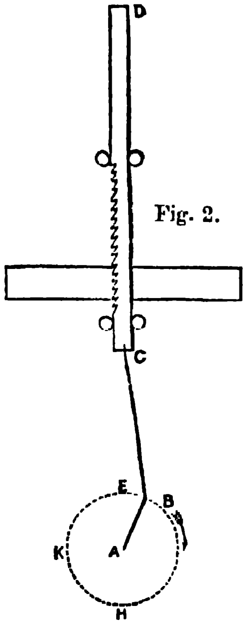


Fig. 2.

We shall now describe some of the different arrangements which are in use for the purpose of regulating the feed, in accordance with the conditions we have determined. The immediate arrangement by which the motion is given to the timber is by means of a pair of rollers, between which the log is tightly held; one of these rollers is acted upon by some one of the different pieces of mechanism which we shall now examine.

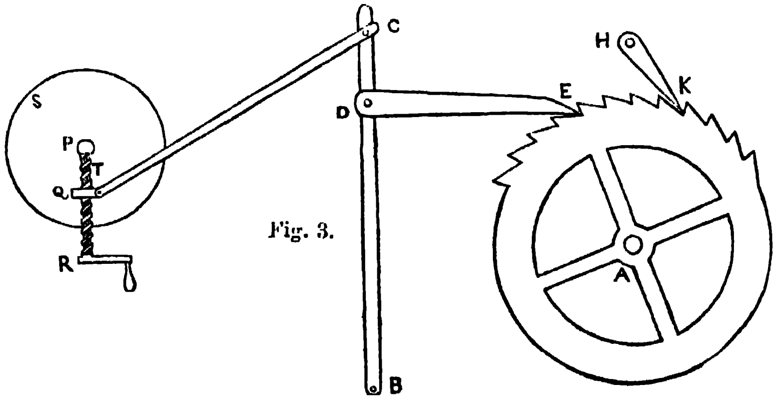


Fig. 3.

The annexed figure (Fig. 3) represents one of the most usual forms of apparatus. A is a ratched wheel, which is connected with one of the rollers by which the wood is advanced to be cut. This ratched wheel is moved by the tooth D E, which is attached to the arm B C, turning around the centre B. It will easily be understood from the figure that when D E is pushed towards the ratched wheel this wheel is advanced, while when D E is withdrawn from the wheel it will fall over the teeth without moving the wheel. It is therefore necessary to provide a reciprocating motion for the arm B C to move the piece D E. P S is a disc which is turned round by the machinery which works the saws, P R is a screw turned by a handle at R, which carries the nut Q. The connecting-rod T C is attached by a pin, about which it can move freely, to the nut Q. When the wheel P S rotates the nut Q describes a circle of which P is the centre. The consequence of this motion of the connecting-rod is that the point C is made to oscillate backwards and forwards, and thus work the ratched wheel.

We shall now explain how this contrivance is able to produce motion of the character which is required for the feed, and then we shall explain the object of the screw whose bearings are embedded in the wheel. The point C moves in the arc of a circle, of which B is the centre. The distance through which C moves is, however, small in comparison with the length of the arm B C. Hence we may without appreciable error consider that the point C moves in a straight line perpendicular to B C, for a small arc of a circle differs very little from the chord of that circle. Since, therefore, one end of the rod C Q moves in what is practically a straight line, while the other describes a complete circle, the motion of the point C must be exactly similar to that of the frame and saws in Fig. 2. In fact, the frame is moved in a straight line by a connecting-rod, the other end of which describes a circle. It follows, therefore, that the motion of C is similar in character, though, of course, different in extent to the motion which actuates the saws.

The point D moves in a similar manner to the point C. This will easily be proved by drawing a consecutive portion of the rod B C to the position shown in the figure. It will then be found that the old and new portions of the point C form with B a triangle similar to the old and new portions of the point D and the point B. Hence the point D moves backwards and forwards with a motion similar to the movement of the saw-frame and the saws.

By means of the piece D E, the motion of the point D is imparted to the circumference of the wheel A. While E is receding, the piece drops from one tooth to the next, and the wheel remains at rest; this is arranged to take place when the saw is being raised, and is therefore out of action. When the saw descends, the piece D E is moved forwards with a motion which gradually accelerates as the velocity of the saw accelerates, and then gradually comes to rest as the cut of the saw draws to a close. Thus the feed is adjusted so that the work proceeds with the utmost uniformity. The object of the detent H K is to prevent any motion of the ratched wheel when the piece D E is being drawn backwards. Were it not for this piece, vibration or other causes might drive the piece of timber from the saws during the up-stroke, and thus the next cut would be less than the proper amount.

So far we have only described the means by which the right character of the feed is given; the actual magnitude of the feed is determined by the position of the nut upon the screw. The amount by which the timber is advanced at each cut depends upon the number of teeth taken up by the piece D E. This depends upon the distance through which D moves at each vibration, and this again depends upon the distance through which C moves. The length of the path which C describes is equal to the diameter of the circle described by the nut Q. This will easily be understood from Fig. 2. It is there evident that the saw-frame oscillates through a space equal to the diameter of the circle described by the extremity of the crank, precisely similar to the motion of the rod C Q in the present case. The point C describes a space equal to twice P Q. Now, by means of the handle R, the nut Q can be approached to the centre P or withdrawn therefrom; and thus the amplitude of the path described by C is capable of the most complete control. The handle R can, of course, be removed when the adjustment has been made, so as not to interfere with the revolution of the wheel and the motion of the connecting-rod.

The only objection to the use of the apparatus we have described is that great exactness of adjustment of the cut is not attainable. The piece D E can be made to take up any integral number of teeth, but cannot, of course, take fractional parts. This inconvenience may be to a great extent obviated by having the teeth very small and numerous: in this case, though only an integral number can still be taken, yet a nicer approximation can be made to the capabilities of the machine. But a far more elegant arrangement is found in what is known as the "silent feed." By the use of this appliance the feed can be adjusted with the utmost delicacy. In fact, the contrivance is equivalent to a ratched wheel with an infinite number of teeth.

In the present series of lessons we have made many references to the force of friction. This force generally appears as a force of resistance to motion; but not unfrequently this very force is made the means of producing motion. If we have two pieces in contact, one of them may have motion without moving the other piece when friction is absent, while when friction is present the motion of one piece of necessity constrains the motion of the second piece also. Here we have friction as the direct cause of the motion of the second piece. It is this principle which is applied in the use of the "silent feed" for sawing machines.

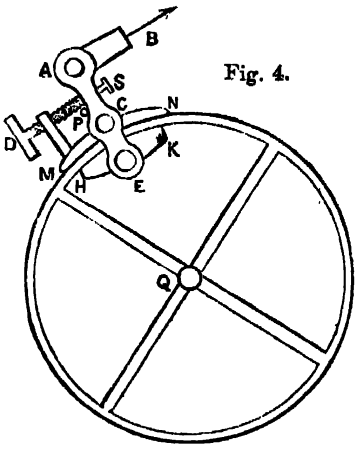


Fig. 4.

In Fig. 4, Q is the centre of a wheel which, when the silent feed is used, replaces the ratched wheel which is attached to the roller that moves the timber. This wheel has a rim on its circumference—it is, in fact, part of a cylinder whose axis is perpendicular to the plane of the power, and passes through Q. The object of this rim is to enable the nipping apparatus to pass clear of the spokes of the wheel.

M N is a saddle which slides upon the outer circumference of the cylinder; A C E is a lever centred at C. H K is a piece which fits very closely on the inside of the cylinder. A B is the connecting-rod, which is made to move in the same manner as the connecting-rod in the ratched wheel. When A B is moved in the direction pointed out by the arrow, the piece H K is pressed firmly against the inside of the rim, and the friction is sufficient to make the saddle and the wheel move in one piece; thus the motion of the connecting-rod makes the wheel revolve precisely as in the case of the ratched wheel. On the return motion of the connecting-rod, the piece H K unlocks, and the lever A E is met by a stop on the saddle P, which restrains its motion from again locking H K; thus on the return the wheel remains at rest. By means of the screw already described, the distance through which the saddle moves upon the rim can be adjusted with the utmost delicacy, and thus the magnitude of the feed is under the most precise control. S is a stop which is acted upon by the screw D. When S is screwed up, the saddle is unable to lock, and the mechanism is thrown out of gear; this is equivalent to raising the piece D E from the ratched wheel.

A second saddle and friction-piece is fixed upon the rim, so as to discharge the function of the detent H K in restraining the motion of the wheel during the up-stroke of the saw.

The machinery which we have described as used in the sawing of timber contains the principal contrivances to be met with in saw-mills; but space does not permit us to treat of several minor details.

CIVIL ENGINEERING.—IX.

BY E. G. BARTHOLOMEW, C.E., M.S.E.

DOCKS.

The Victoria "London" Docks deserve a special notice, on account of the magnitude and perfection of the works carried out in connection with them. They occupy a position in a direction east and west, across a promontory separating Galleon's Reach on the east from Bugsby's Reach on the west; the original idea in placing the docks in this locality being to afford them an entrance at each extremity, opening into either reach, whereby the entrance and departure of vessels would be greatly facilitated. The original conception has not as yet been carried out, but the land necessary for completing the undertaking has been purchased by the company.

The docks now in operation occupy the western portion of the promontory, and possess a water-area of nearly 100 acres, of which the main dock alone exhibits a magnificent sheet of water of 80 acres, whilst the tidal basin and entrance-lock exceed 16 acres.

The basin and dock together are 4,050 feet long, and 1,050 feet wide at the level of high-water mark. Vessels enter by two pairs of lock-gates from the Thames into the tidal basin, which is separated by a dumb jetty, with a single pair of gates, from the main dock. In the latter are four jetties, projecting 581 feet into the dock on the north side, for the loading and un-loading of vessels. Each jetty is 140 feet wide, and there is a space of 480 feet between them, with 550 feet of water intervening between the most easterly jetty and the eastern boundary of the dock. By this arrangement quay-room equal to nearly three miles is provided.

The bottom of the basin and main dock is 24 feet below Trinity high-water mark, whilst the depth gradually increases to 25 feet 8 inches in the channel leading from the lock to the basin, diminishing 2 inches on the sill of the inner gates, and then increasing to 28 feet on the sill of the outer gate, and through the entrance into the river; the mean fall of tide at the entrance is 18 feet.

The top of the copings of the entrance and entrance-lock walls corresponds with the level of the old river bank, which protects the marsh-lands in this locality from the overflow of the tide; and this is maintained at the height of 5 feet above Trinity high-water mark.

The soil which was excavated for the formation of the docks consists of a stratum of yellow and blue clays of various thicknesses, altogether about from 5 to 6 feet deep, then a stratum of peat from 5 to 12 feet thick, and then a bed of gravel lying upon the London clay, the gravel varying from 7 to 10 feet in depth. The solid clay was thus found at an average depth of 37 feet below Trinity high-water mark, and 6 inches below this the brick-work of the gate-platforms was laid.

The side-walls of the lock and entrance are throughout constructed of cast-iron piling and plates, backed with concrete, the only omissions being where the brickwork is inserted for the gates. The piling slopes 2 inches in the foot, and the copings opposite the iron pilings are 91 feet apart. There is no slope or batter given to the brickwork, and the walls are 80 feet apart. The dimensions of the lock-chamber are, 326 feet 6 inches long from gate to gate, 80 feet wide at bottom, with 10 feet depth of water on the sill at low water. The piled and concrete walls recommence at the extremity of the brickwork which forms the sides for the entrance-gates, and is carried forward for nearly 400 feet upon the left hand of the entrance, and 160 upon the right hand. We have in a former paper (No. VIII.) alluded to the iron piling and plates employed at Brunswick Wharf, Blackwall. That employed at the entrances and lock-chamber of the Victoria Docks is somewhat similar, and we will now enter into the details of its construction, as being a matter of great importance in marine engineering. The cast-iron piling is formed in bays, which are 7 feet 1 inch from centre to centre of the main piles, the space intervening being filled for a distance of 15 feet from the top by three cast-iron plates, retained laterally by the edges of the main piles which stand in front of them; the space below the plates being occupied by four cast-iron sheet piles, on the top of which the lower plate rests, the lower edge of the plate being formed with a fillet, which overlaps and hides the top of the piles, and holds them in their position. In Fig. 15 we give elevations and sections of the plates and piles. The plates are strengthened at the back by cross-feathers, A A A, and fit one into the other by overlaps as seen at B B in the section. The main piles (Fig. 16) are each in two lengths, the bottom portion being 25 feet long, and 18 inches wide on the face. They are strengthened by two vertical feathers or flanges (C C in the section) at the back, 8 inches deep, 12 inches apart, and 2 inches thick. The upper pile is 12 feet 8 inches long, and 18 inches wide, and is similar in section, but lighter in make. The two fit one into the other, the top portion being cast with fish-pieces, F F, for the purpose, and bolted together through the fish-plates. The sheet piles are in one length of 20 feet, somewhat similar in section, but furnished with a lip, L (Fig. 17), on one side, to overlap the adjoining pile. In the rear of each main pile, and at a distance of 18 feet from it, a timber tie, 20 feet long, is driven to the same depth as the cast-iron pile. Through the head of this tie two wrought-iron rods, 2 inches in diameter, are passed, and secured by washer-plates and nuts. The lower tie-rod is connected with the upper end of the bottom portion of the main pile by means of an eye-bolt passed through the hole H (Fig. 16); and the upper tie-rod with the upper portion of the main pile at a distance of 8 feet above the other rod in a similar manner through the hole H′. The main piles are driven 5 feet into the gravel, and the sheet piles 2 feet 6 inches.

Between the inner gate and the basin, the channel was excavated to a depth of 27 feet 8 inches below Trinity high-water mark, and the bottom puddled with clay to a thickness of 2 feet. The concrete at the back of the iron plates is carried to the same depth as the bottom of the clay puddle, and the entire space between the concrete and the land-ties is filled in with gravel, well rammed. In the lock-chamber the gravel in the bottom was taken out down to the clay, except at the sides where the piles are driven, and here concrete is laid, sloping from the wall downwards towards the centre, the intervening space being filled with clay puddle to the necessary level.

Below the entrance-gate the concrete wall occupies the entire space between the sheet-piling and the land-ties up to a level with the top of the latter, when it is reduced in thickness to about 10 feet, and then carried up vertically. The wharf wall is finished off at the top in front by a stone coping, 18 inches thick, and 3 feet broad.

In consequence of the London clay forming an impervious foundation at a convenient depth under the gate platforms, it was not necessary to use inverts, but ordinary brickwork, in level courses, was employed. A sufficient area for the respective platforms was laid bare down to the London clay, and round these areas a single row of elm sheet piles, 16 feet long, and 8 inches thick, was driven close to a depth of about 6 feet into the solid clay, and within the areas so enclosed the brickwork of the platforms was laid—in the case of the lower gates to a thickness of 8 feet 6 inches in that part of the platform traversed by the gates, and of 9 feet 6 inches in the remaining part; whilst in the case of the upper gates, the thickness of the brickwork is 6 feet 6 inches under the gates, and 7 feet 6 inches in the remaining part. The great object in securing a perfect union between the brickwork and the clay is to prevent the water from getting under the platform and blowing up the brickwork; the sheet-piling around effecting the same object with regard to the side-joints of the brickwork. Upon these admirably constructed platforms, the side-walls are carried up, being built of brickwork 20 feet thick, except where the recesses for the gates are left.

The lock-chamber is connected with the outer channel and the basin respectively by two cast-iron pipes, each 5 feet in diameter, which form the medium for the passage of the water for filling and emptying the chamber. Near the middle of these pipes are placed the paddles or sliding-plates for closing the passages. These paddles are of cast iron, faced with brass, and are lifted and lowered by hydraulic power.

The gates, of which there are three pairs—viz., two to either end of the lock-chamber, and one in the jetty separating the basin from the main dock—are constructed almost entirely of wrought iron; the two former have each a span of 40 feet, and a height of 31 feet, and are very considerably curved, the versed sine of the arc formed by them when closed being 20 feet, or one-fourth of the span. The gates may in general terms be described as consisting of two skins of wrought iron, separated from one another by transverse plates, strengthened with angle-irons. The joints being riveted and water-tight, each gate possesses a low specific gravity in water. The curvature of the inner and outer skins is different, the outer curve being an arc of a circle having a radius of 50 feet, and the inner that of a circle whose radius is 59 feet 9½ inches; the result of this flatness in the inner curve being to make each gate thicker in the middle than the ends, the ends being 24 inches apart between the skins, and the middle 36 inches apart. The skins are kept apart by a series of horizontal plates, varying in vertical distance from each other, being nearer at the bottom, and increasing in distance towards the top. The bottom plate is three-quarters of an inch thick, and to it is secured the timber which meets the shutting-sill, the latter being of cast iron. The other plates are half an inch thick, and are connected to the skins by T and angle irons. The interior of the gate is further strengthened by vertical plates, which pass continuously from the top to the bottom, intersecting each horizontal plate. There are two of these vertical plates in each gate, thus dividing the entire gate into three nearly equal vertical divisions, irrespective of the horizontal divisions. It is obvious that by this arrangement the gate becomes a structure of exceeding strength, combined with great lightness; and the large space which exists between the various diaphragms permits of access to all parts of the interior for cleaning, repairing, etc., by means of man-holes, which each compartment is provided with. Covers also are provided for the man-holes, and thus the requisite amount of weight or power of flotation is given to the gates by the introduction or withdrawal of water. The thickness of the skin varies from about three-quarters of an inch at the bottom to three-eighths of an inch at the top. It consists of wrought-iron plates, riveted together, the plates being placed vertically; every joint having a strip of iron both outside and inside, to ensure its being thoroughly water-tight. The heel and mitre posts are of timber, strongly bolted to the vertical plates which form the ends of the gates. Great care had to be taken to prevent leakage into the gates through the bolt-holes. The gates are turned by hydraulic power, applied through the medium of a chain 1¼ inch diameter, communicating a maximum force equal to about 7 tons per square inch of chain section. The chains are attached to the gates at a point 2 feet above low-water mark, passing through an eye-bolt having a sectional diameter of 2½ inches, with an attachment to both skins.

The pivot-cross upon which each gate rests and turns consists of a strong cast-iron cross, each arm being 5 feet long from the centre, cast hollow upon the under side, and having oak timbers 15 feet long fixed to each arm, the arms being securely fixed to the brickwork of the platform by 2-inch bolts, passing down through 8 feet of solid brickwork into thick cast-iron plates embedded in it at that depth, whilst two of the arms of the cross are built upon by the side-wall of the lock-chamber. The pivot itself is of cast-iron, 6 inches long, and accurately turned to a diameter of 11 inches.

The shutting-sill, which is of course curved to correspond with the inner curvature of the closed gates, is composed of eight cast-iron segments. Its section is that of angle-iron, 2 inches thick, but varying in height and breadth from 12 inches and 18 inches in the centre to 21 inches and 27 inches respectively at the ends. At the extremities, the sill is bolted to the pivot-cross. At every 2 feet there is a back feather uniting the extremities of the angle, in order to strengthen it. The sill is bolted down to the brickwork by bolts passing up through it from a cast-iron plate laid in it at a depth of 8 feet at the time of building. The bolts are 2 inches and 1½ inches in diameter, and each segment is secured by ten of the former and five of the latter.

The position of the roller upon which a gate rests must be determined by a consideration of the proportion of the weight of the gate it is intended to bear. If it be placed quite at the extremity of the gate—that is, near the mitre-post—it is obvious that the weight of the gate is fairly divided between it and the pivot; and the nearer it is placed to the latter, the greater is the proportion of weight resting upon it, until when it lies in the intersection of the vertical planes passing through the centre of the pivot and the centre of gravity of the gate, in which position it bears the entire weight of the gate. If the gate were a *straight* gate, the roller would naturally be fixed somewhere *under* the gate; but in the case of a curved gate, there are other considerations involved, and it has been found desirable to place it outside the outer curve. The rollers upon which rest the gates we have been speaking of are of cast iron, 7 inches

MAIN PILES.

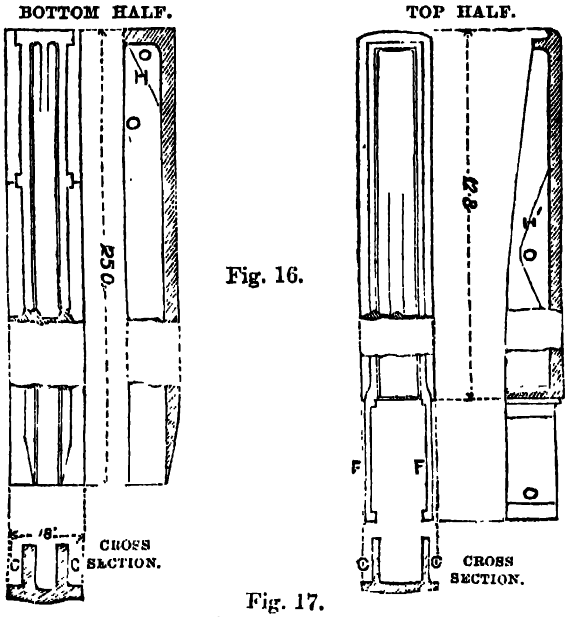
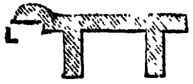


Fig. 16.

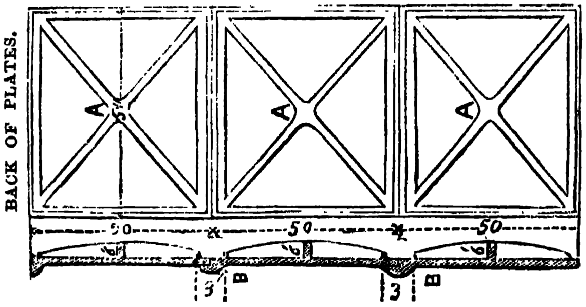
Fig. 17.



SECTION OF SHEET PILE.

Fig. 15.

ELEVATION.



SECTION.

wide, and 32 inches diameter, and, by an ingenious arrangement, can at any time be removed for repairs. The roller-path is also of cast iron, 4½ inches wide and 8 inches high, having the section of a bridge rail, and bolted through 15-inch wide timber to cast-iron plates set in the brickwork.

The anchor or supporting piece for the upper pivot of the gates is of cast iron, in the form of a sextant, being 11 feet from the centre of the pivot to the outer curve. It is bolted down to immense bed-plates of iron set 10 feet deep in the brickwork of the side-wall. The strap which secures the gate to this casting is of wrought iron, 7 inches deep, and 2 inches thick in the arms, but increasing to 5 inches near the centre, at the part which suffers from the friction of the axis. This axis is 18 inches in diameter, made of wrought iron, and riveted to a ¾-inch iron plate on the top of the gate. The strap is adjusted in the usual manner by keys.

There is a slight difference in the size of the lower gates as compared with the upper and inner gates, but they are all of substantially the same character in the mode of construction. The gates which enclose the lock-chamber are worked by hydraulic power, which is not the case with the inner pair, the advantage of hydraulic power being seen from the fact that the lock-gates can be opened in 1¼ minutes; the latter have the sluices in the gates themselves, and not in the side-walls.

Upon each of the five jetties alluded to in the early part of this paper is constructed a substantial warehouse, comprising an upper floor, a ground floor, and vaults, of nearly an acre each in extent, being 500 feet long and 80 feet broad; and upon the space intervening between the roof of the warehouse and the edge of the jetty are placed hydraulic cranes, nine cranes to each jetty. The most powerful crane upon each jetty is at the extremity, and is capable of lifting 5 tons; the others are 2-ton cranes. The side-walls of the jetties are vertical, and consist of cast-iron piles placed 7 feet apart from centre to centre, with 14-inch brickwork, set in Roman cement, filled in between the piles. The brickwork panels are inverted arches, the concave side towards the water, the inner surface being backed first with concrete and then with clay. Each cast-iron pile is 35 feet long, and weighs 1¾ tons, and is connected with its corresponding or opposite pile upon the other side of the jetty by two tie-bars of 2-inch round iron and 140 feet long, fixed to the piles at 5 feet and 17 feet respectively below the head of the pile; the piles enter the ground 4 feet below the bottom of the dock. The foundations of the jetty walls are of concrete, 3 feet thick, carried up one foot above the bottom of the dock, and upon this the brickwork is laid. The top edge of the wall is covered with a cast-iron piping, bolted down to the heads of the piles.

The entire dock possesses 145 hydraulic cranes, the necessary pressure being obtained by two 60 horse-power steam-engines, consuming on an average 17 tons of coal per week. In order to convey the water-pressure from one side of the dock to the other, a culvert is constructed under the entrance from the basin to the lock-chamber, terminating at each side in a well; in this culvert the water-pipes are laid, the same culvert being made available for telegraph-wires.

ɅINING AND QUARRYING.—X.

BY GEORGE GLADSTONE, F.C.S.

IRON.

ɫ — FORM OF REFINERY — PROCESS — QUALITY OF ;R'S METAL—PUDDLING—THE FURNACE—PROCESS ɈALITY OF PUDDLED BALL.

now to deal with some very important operations for g the crude iron into a malleable article, and to which vo-thirds of ıl produced have to be , the only

such being for foundry purposes. The special qualities which render iron so preeminently useful are only brought out by the processes which have now to be described.

The first step is *refining*, and then *puddling*. There are modifications of the second, by some of which the first can be dispensed with; these are of recent introduction, and have not yet superseded the older plan.

Refining.—The object of this process is to remove by oxidation the foreign ingredients which are present in all crude iron, and which were shown in the preceding article to be deleterious to the metal. The refinery or running-out fire will best be understood by reference to the accompanying diagrams (Figs. 7 and 8), representing a sectional elevation and ground-plan of one of these furnaces. It will be seen to consist of a flat hearth, A, with six water-twyers pointing into it. The walls of the hearth at the sides and back consist of three hollow iron troughs, B, B, B, through which cold water is made to flow continually; the front wall being a solid iron plate, with a tap-hole, C, at the bottom of it. The uprights, D, D, in the two sides are made of iron, and support a chimney, but the front and back are movable, the iron plates of which they consist being hung as folding doors. The floor of the hearth and the sloping piece E are protected by a coating of sand; and F is the running-out bed—a long, shallow mould made of iron.

The fuel used in refining is either the purest coke that can be had, or else charcoal; and the blast is supplied cold. The hearth is filled with coke, which is thrown in through the door at the back; upon this about 20 to 22 cwt. of pig-iron are laid; and upon this again more coke is then heaped up. Fire is applied, the doors closed, and the blast turned on. In the course of about an hour and a half the iron has melted and run to the bottom, but the twyers being pointed downwards upon the surface of the metal at a considerable angle, the liquid iron is kept in active motion, and the whole is then subjected to the oxidising influence of the air. In the course of another half-hour the furnace is ready for tapping, when the iron and cinder, or slag, flow out together into the running-out bed; the latter, being of lighter specific gravity, rises to the surface; and the cooling is expedited by throwing cold water upon it. The application of the cold water not only does this, but it facilitates the separation of the cinder, and also renders the iron more brittle, a matter of some consideration, as it has to be broken up into small pieces before being put into the puddling furnace.

The refined iron, or finer's metal, is no longer grey, having parted with the greater part of its carbon; it should now be compact, and almost silvery in lustre. During the process a portion of the carbon and the sulphur has been oxidised and dissipated by volatilisation, and the silicon has combined with a portion of the iron, forming the cinder. Thus a white pig-iron,

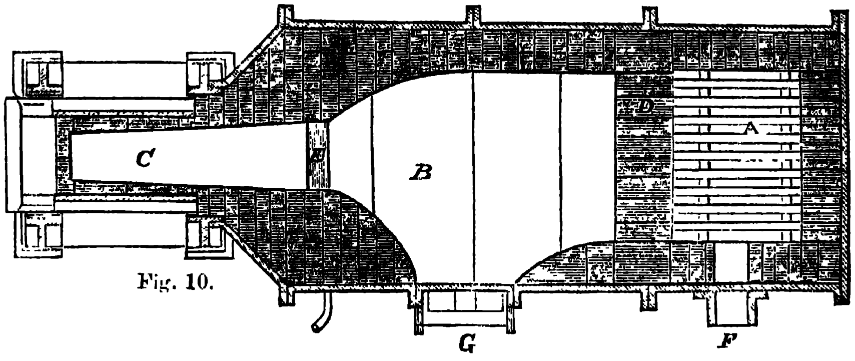


Fig. 10.

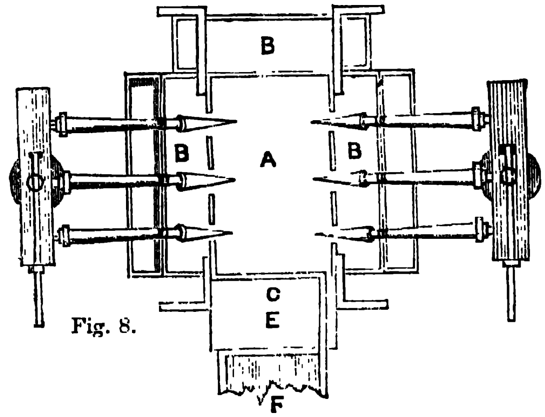


Fig. 8.

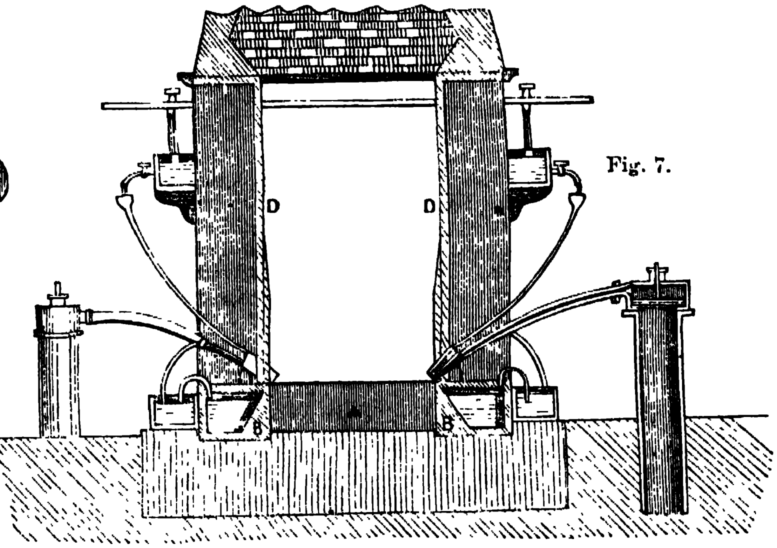


Fig. 7.

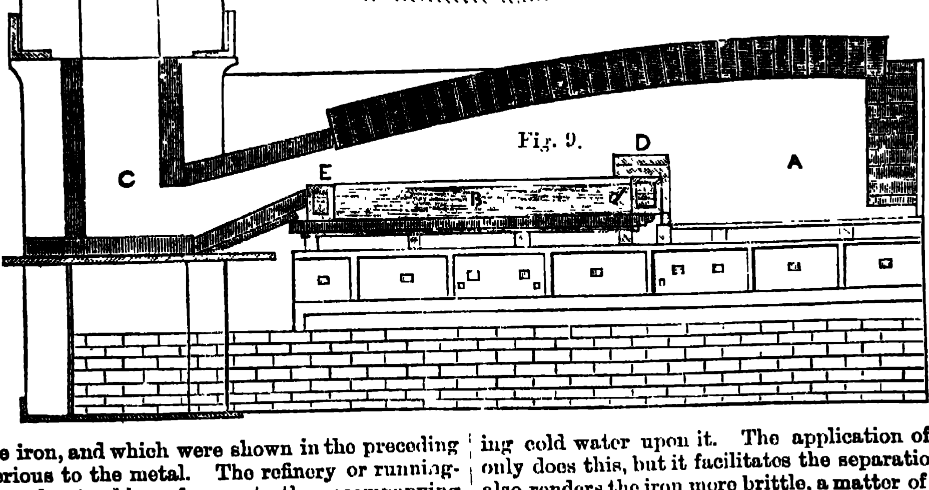


Fig. 9.

containing 1·27 per cent. of silicon and 0·93 per cent. of sulphur, has yielded refined metal containing only 0·14 per cent. of the former and 0·52 per cent. of the latter. This gain in the quality of the iron is not attained without a considerable loss in weight, which varies from 10 to 17 per cent., though the iron and cinder together will exceed the weight of pig-iron operated upon. Thus a charge of crude iron of 2,498 lbs. will yield 2,240 lbs. of refined metal and 325 lbs. of cinder, showing an increase of 69 lbs., due to the absorption of oxygen, and to the taking up of some earthy matter from the fuel, and sand from the floor of the hearth, all of which must be looked for in the cinders, together with the iron which has been lost. An analysis (of which the following cinder from Dudley is a specimen) will confirm this. It contained—

Protoxide of iron	61·2
Silica	27·6
Alumina	4·0
Phosphoric acid	7·2
	100·0

This analysis also shows that the iron from which it came has also been relieved from the presence of a large per-centage of phosphorus. A slag containing so large a quantity of metallic iron is, of course, not wasted; but is re-smelted or used for other purposes.

Puddling.—The finer's metal now passes into the hands of the puddler, who employs another furnace of special construction. It is made upon the reverberatory principle, as shown in Figs. 9 and 10, which represent one of these puddling furnaces of modern type, in ground-plan and elevation. It will be seen to consist of a fire-place, A, with a hearth, B, and flue, C, separated by the bridges D and E. The fuel is put into the fire-place through the aperture F, and the iron into the hearth by the larger one at G. This is closed with an iron door lined with fire-brick, which can be raised at pleasure by a lever and chain; and the top of the flue is provided with a damper which can be regulated in the same manner. Through a small opening in the lower part of the door G, the puddler introduces his long iron bars (the rabble and the paddle) with which he manipulates the iron. The former is a wrought-iron bar, about 8 feet long, rounded at the end held by the puddler, with a piece of flat iron 2½ inches broad, and set at right angles with the rod, at the other. The puddle is rather lighter, with a bevelled edge at the end, like a dull chisel. In this furnace the sides of the hearth, as shown as E and *d*, are made of hollow iron tubes, through which a stream of water is made to pass to keep them cool. The bottom of the hearth is now always made of plates of cast iron, on the under side of which the air is allowed to circulate freely, with the same object. The floor and sides of the hearth are covered with a bed of cinder called "bull-dog," either from previous puddlings or from the refinery, and plastered over with a paste or "fettling" made of red hæmatite or other oxide of iron. Immediately below G is a smaller opening connecting with the hearth, which is called the tap-hole. The furnace being quite separated from the hearth by the bridge, coal is generally used as the source of heat.

The operation of puddling, called by the workmen "a heat," occupies from an hour to an hour and a half. About 4½ to 5 cwt. of iron are puddled at each heat. Sometimes refined metal is used alone, that is, when the best qualities of iron are to be produced; at other times it is mixed in variable proportions with ordinary pig-iron. Some hammer-slag or mill-scale is added, which is all the better if it has become a little rusty, the object of it being to supply an additional quantity of oxygen. The refined and pig-iron having been broken up into small pieces, is piled up round the sides of the hearth; the fire is got up to its full heat by raising the damper, and it is left for about twenty minutes. By that time the iron is just beginning to melt, and the furnace from this time onwards requires the constant attendance of the puddler and his assistant. The temperature of the furnace has to be carefully attended to; and the iron has to be continually stirred and worked with the rabble, so as to bring all parts of the charge to an equally pasty condition. This occupies about a quarter of an hour, during which the damper is regulated so as to prevent the iron from becoming too fluid, when the "boiling" commences, and a full heat is again supplied. This apparent ebullition is due to the combination of the carbon in the iron with the oxygen supplied by the hammer-slag or scale, and formation of carbonic oxide, which is volatilised, and causes the iron to swell up in its efforts to escape. Stirring is kept up continually—the boiling gradually ceases, and presently the puddler finds the iron beginning to "come to nature," indicative of the process being complete. This is known by the iron becoming sticky and working heavy, the cinder separating from it in a very liquid state. Any further oxidation of the iron must now be checked, or a loss of metal would be the result, and the damper is therefore let down. The puddler has now to work up the iron into balls of about 80 pounds each, which are withdrawn from the furnace as soon as made. The cinder is finally allowed to run out at the tap-hole.

The effect of the puddling is still further to remove the carbon, silicon, sulphur, phosphorus, and other impurities of the pig-iron; the tap-cinder drawn from the puddling furnace being very similar in its composition to that which comes off in the refinery. When the raw pig-iron is puddled the quantity of cinder produced is inconveniently large, and if none but refined metal be used, the want of a little is sometimes felt; a mixture of the two generally works very well. In order to ascertain with more precision the nature of the chemical action during the puddling, experiments have been made by drawing samples at different stages of the process, and analysing the metal. The pig-iron operated upon was composed of the following:—

Carbon	2·275
Silicon	2·720
Phosphorus	0·645
Sulphur	0·301
Manganese and aluminium	traces
Iron	94·059
	100·000

The first sample was drawn forty minutes after it had been put into the puddling furnace, and was analysed for the carbon and silicon; the succeeding samples were drawn at various intervals, and similarly analysed, the whole series being as under:—

40	minutes,	2 726	per	cent.	carbon,	0·915	per cent. silicon.
60	,,	2·905	,,		,,	0·197	,, ,,
65	,,	2·444	,,		,,	0·194	,, ,,
80	,,	2·305	,,		,,	0·182	,, ,,
95	,,	1·647	,,		,,	0·183	,, ,,
100	,,	1·206	,,		,,	0·163	,, ,,
105	,,	0·963	,,		,,	0·163	,, ,,
110	,,	0·772	,,		,,	0·168	,, ,,

at which time the puddling was complete. It will be seen that nearly all the silicon is driven off at an early stage of the process, but that for some unexplained cause there is during this same period an actual increase in the quantity of carbon; the final result, however, is that the puddled ball only retains about one-third of the quantity contained in the iron at the commencement of the operation. The increase of carbon at the earlier stages has been observed by other experimenters. The greater part of the phosphorus and a little of the sulphur passes into the cinder, as will be seen by the following analysis of the tap-cinder resulting from the experimental operation detailed above:—

Silica	16·53
Protoxide of iron	66·23
Sulphide of iron	6·80
Phosphoric acid	3·80
Protoxide of manganese	4·90
Alumina	1·04
Lime	0·70
	100·00

The operation of puddling as ordinarily conducted is a somewhat expensive one, as the furnace itself only lasts about six months, even when repaired weekly; and a large number of these are required, 25 tons per week being the maximum output of each furnace. The consumption of coal is about equal in weight to the iron produced; and there is an average loss in weight during the process of about 10 per cent. of metal. In addition to this the cost of labour is high, as the work of the puddler and his assistant is exceedingly severe: the prospect of very high wages is consequently necessary in order to induce men to learn the art, especially as it is one in which proficiency is only acquired after long practice.

Before considering the treatment to which the puddled balls are subjected to convert them into bars, one or two other plans of producing them must be described, which will be taken up in the next article.

OPTICAL INSTRUMENTS.—XI.

BY SAMUEL HIGHLEY, F.G.S., ETC.

LANTERN DEMONSTRATIONS (*continued*).

In *literature*, the memory may be assisted, by corresponding illustrations, to recall types of the peculiarities of style of that "best of all good company," the great writers of all ages. Thus many "half hours with the best authors" might be advantageously spent in the school-room; and where poetry has been set to music, the notes of the tune might be projected on the screen, so that a large class may join in unison.

Magic lantern slides in the ordinary way are kept in boxes, but I regard this as great waste of educational material. If the slides represent natural history subjects, they should be placed in the museum-cases beside allied objects for every-day inspection, care being taken to fix them at such an angle, that light is reflected through them by aid of white paper placed beneath; or by mounting the slides in long frames, backed with ground glass, they may serve as appropriate borders to the windows of any scientific or educational institution.

The advantages claimed for lantern demonstrations are that the most important optical laws, together with many other physical experiments, can by their means be strikingly illustrated, and by the employment of photographically produced slides, a wide range of subjects can be pictorially illustrated on a large scale, in a cheap and efficient manner; that such delineations are truthful to Nature and abound in detail, to an extent ordinary hand-painted diagrams cannot compete with; that when taken direct from Nature or from artistic productions, correct as to the rendering of light and shade, the large and impressive image when projected on the screen stands forth with perfect stereoscopic effect, so that the lecturer is enabled to fix the attention of his audience upon the subject he is describing in a manner not attainable with the ordinary tiers of small paper diagrams, over which the eyes of students too often listlessly wander, while from the magnitude of these lantern pictures, the most microscopical details can be made distinctly discernible even in the largest lecture-hall; that by thus appealing to the eye, or "sight knowledge," we do the next best thing to showing the objects of the discourse themselves, and so establish a system of artificial memory, by aid of which we can teach many subjects quicker and better than the most impressive verbal description, *unillustrated*, could ever attain to, and in a manner not so likely to pass out of mind, a matter of the greatest consequence when a wider range of knowledge is expected from educated people at the present day; that the educational value of such coloured transparent diagrams need not cease with their exhibition in the lecture-room, for they may be used as museum specimens or window decorations. In conclusion, I would say, it is desirable that every exploring expedition should be accompanied by its official photographer; that every national museum, hospital, and astronomical observatory should have its appointed photographic operator; and then the hoped-for time may come, when we can, in systematic manner, place the records of scientific travel, the transcripts of Nature's treasures, mementoes of fell disease, and the self-depicted aspect of the heavens, upon the screens of our lecture theatres, so that we may take our students over the world, or into the depths of space.

SOURCES OF LIGHT.

The means of securing a beam of light of various degrees of intensity, size, and physical properties, is not only essential to the optical experimenter and demonstrator, but also to the operator in several branches of trade. First in rank, as to intensity and physical power, stands sunlight; then in order, the electric light, the lime-light, the magnesium and zinc lights; then Argand lamps fed with petroleum, paraffine, ozokerite, oils, and gas impregnated with hydro-carbon vapours, chlorochromic acid, bisulphide of carbon, magnesium ethyle, etc., down to candles and the artificial star.

I shall proceed to describe a type of these several sources of light, always selecting what, to the best of my judgment and experience, I consider the simplest and best arrangement; as much may be attained in the construction of philosophical instruments by the simplification of parts.

The Solar Reflector.—This arrangement enables us to reflect the solar ray into any piece of apparatus or room, suitably situated, we wish to illuminate with a powerful beam of light, and to keep the rays on a fixed spot. To the photographer this arrangement is invaluable for the production of "enlargements" from small negatives of portraits, landscapes, etc., as no known light is so photographically energetic as that derived from the sun. By experimentalists, and those engaged in teaching science, much may be done with the solar reflector, where the trouble and expense of employing artificial sources of light of great intensity would be regarded as a drawback to frequent work. Its construction involves two adjustments, one of inclination, the other of rotation, so that the sun may be followed in its course, and that its rays may be reflected constantly in one direction.

Some years ago this arrangement was much used for microscopic demonstration, but the lime-light and electric lantern rendered its use, to a great extent, obsolete; and its resuscitation is due to photographic requirements, for while the latter sources of light can be brought into play at any desired moment, the solar reflector can only be employed when the sun shines, a matter of great uncertainty in this country.

The old-fashioned arrangement is shown in Fig. 31. A clamped board, the size of a suitably situated window, is rabbeted to fit the frame closely, so as to exclude all light at the edges, and is kept in place by thumb-screws or wedges. In the centre a round hole is cut, of a size proportionate to the apparatus to be used, which is screwed into a flange attached to the inner or room side of the board. To the outer side of the carrier-board a disc of wood or metal is attached by a suitable counter-sunk fitting to the central aperture; this disc carries on projecting arms a long narrow glass reflector. This disc can be rotated from inside the room by means of a handle that works through a curved slot in the carrier-board, by which motion the mirror can be made to follow the course of the sun, while the proper inclination is given by means of an endless screw working on a racked wheel attached to the axis of the mirror. Some practice is required to keep the beam central, or in one constant direction, as by this arrangement there is a tendency for the mirror to move in jerks. To obviate this defect it is better to effect the rotation by means of a pinion acting on a racked flange (that takes the place of the counter-sunk fitting) connected with the outer disc. The pinion may be turned by a large milled head, or by a lever arm that fits the pinion by a square key-head, by which a more equable motion is secured.

A simpler, cheaper, and better reflector may be thus constructed, and is shown in Fig. 32. A carrier-board, B B B, has a rabbet cut round its edges, by which it is fitted light-tight to a window-frame. About the middle of this board a round aperture is cut to admit the reflected light into the operating-room, and on the inner side of this a brass flange, *ff*, is fitted, into which the condenser, or other apparatus, can be screwed. Below this aperture a rotating brass arm, R, fits with a smooth and even action (by aid of a clamp, C), on to which the mirror elevator (or depressor), E, is hinged at H. This elevator is a square brass arm, from which projects, at a right angle, a curved limb, pressing against a stout screw, S, that works through the axis of the rotating arm R; and it will be seen that as the screw S is turned outwards or inwards, so the arm E will be raised or depressed. The mirror M is fitted in a metal frame, and can be fixed to the arm E by means of a binding-screw, *s*, fixed to the back of the mirror-frame. The rotation of the mirror is effected by a long lever arm, L, that fits by a square key-head on to the rotating arm R. This arrangement allows of several mirrors being used for various purposes—viz., an ordinary mirror of *thin* glass silvered at the back, or a speculum made by depositing silver by the processes of Liebig and Petitjean on a surface of glass worked parallel, or a black mirror, made by roughing the back with emery, and then coating it with asphalte varnish, in which a portion of india-rubber dissolved in benzole (to give elasticity and prevent cracking) has been added. Such a mirror gives a clear, bright image of the sun, and light enough for most experiments, and when set at the proper angle gives a beam of polarised light;

or when a powerful beam of polarised light is required, the mirror may be composed of several sheets of thin, even glass placed one over the other, forming what is technically termed a "polarising bundle;" or when a soft light is required, as in photo-micrography, a "white cloud" mirror may be employed, which is made of a sheet of opal glass, in some cases the rough surface, in other cases the polished or plate-glass side being placed uppermost to reflect the light. These mirrors must be made long in proportion to the diameter of the condenser employed, and somewhat wider than the aperture into which it fits.

I may here state that it is better to mount any necessary apparatus on a stand, independent of the reflector and its condenser, so that should the latter be shaken by the wind in a manner to threaten the result of an experiment (as in photographic work), the two parts can at once be isolated by interposing a screen; and it also allows of greater freedom of action in disposing appliances and getting to the several component parts of any complicated arrangement of apparatus.

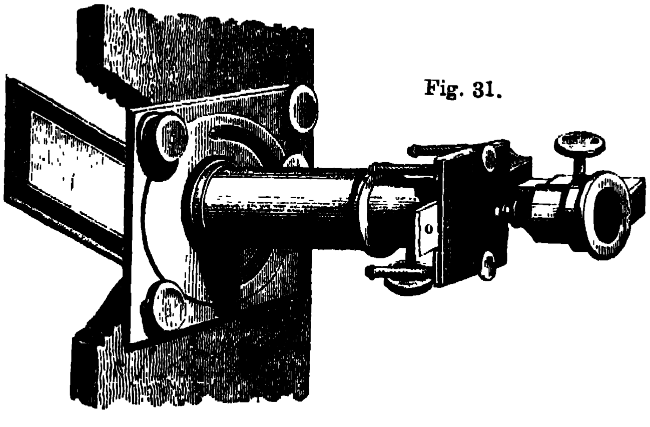


Fig. 31.

The Heliostat.—In the instrument above described all the adjustments are made by hand, and where the experiments are intermittent they answer the purpose, for a practised operator can keep the light central with the axis of any optical arrangement sufficiently long for such purposes; but when it is necessary to keep the cone of light (concentrated by a condensing lens from the reflecting mirror) *absolutely* central for a lengthened period on a fixed spot or direction—as for certain astronomical purposes, delicate physical investigations, and photographic enlargements—then the requisite adjustments must be produced automatically (self-acting). To effect this, motion is imparted by a "driving clock," so that the axes of the several parts of the adjustable mirror may, for twelve or twenty-four hours, turn with a determined velocity; and definite positions are assigned to the component parts of the arrangement, which are deduced from the same laws that regulate the motion of the earth about its axis. Such instruments are called "heliostats."

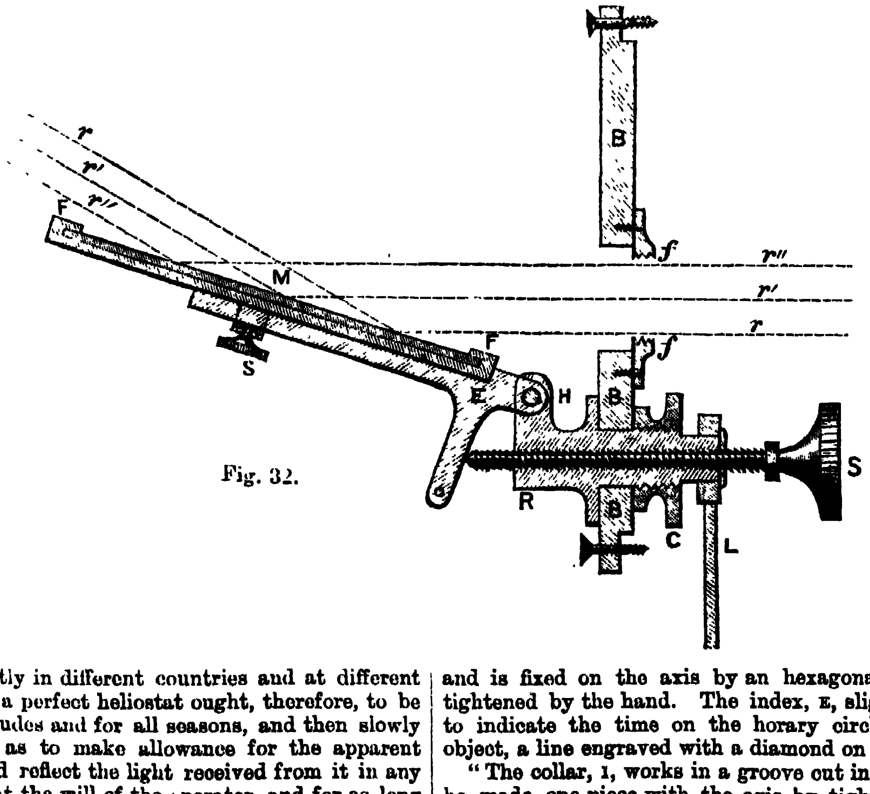


Fig. 32.

The sun, as we know, follows a path which varies incessantly in different countries and at different periods of the year; a perfect heliostat ought, therefore, to be adjustable for all latitudes and for all seasons, and then slowly move in such a way as to make allowance for the apparent motion of the sun, and reflect the light received from it in any direction whatsoever at the will of the operator, and for as long a period as he may desire. The contingencies of this problem are met in the exquisite arrangement of Silbermann, but his heliostat is more complicated and costly than is necessary for most practical requirements; as a heliostat is generally used in a fixed locality, and the reflected beam is usually required in a horizontal direction, consequently adjustments for varying latitudes may be dispensed with, and the arrangements for inclination and centreing greatly simplified. The two most useful heliostats for practical purposes are those of Fahrenheit, as modified by Monckhoven, where a large beam of light is required, say from eight to nineteen inches in diameter, and which can be used as well on the 21st of December—the time at which the sun, in this part of the world, is at its lowest—as on the 21st of June, when the sun is at its highest; and the arrangement of Colonel Woodward, as modified by Dr. Maddox, where a small beam only is required for refined experiments and operations.

The following description is given by Dr. Van Monckhoven, in his treatise on "Photographic Optics:"—

"The table N (Fig. 33) is of turned and polished iron. It is supported on three screws, one of which is seen at O, and presents at its centre a conical fitting, about which turns the piece L M, capable of being made fast to it by tightening the screw *a*. This table is rendered horizontal by means of a good spirit-level.

"The support, J K L M, is of iron. The arc, J K, necessary for the adjustment for latitude, is movable, but is fixed by the maker to the latitude for which the instrument is required. No attempt, therefore, must ever be made to disturb the setting, J K.

"To the piece J K L M is fixed the arm-rest in which the axis A turns, as the figure sufficiently explains.

"The axis, A, is of steel, fixed by a screw to the arm-rest, P Q, and rests upon the brass screw, B, which serves to bring the several pieces into position. The screw B is made fast by a side-screw. The parts of the axis touching the bearings must be always well lubricated with a mixture of paraffine and oil.

"The toothed circle, C, is fastened to the axis by a screw, of which the thread runs the reverse way, so that it may not get loose by the rotatory movement of the axis. This screw also is securely fastened. The wheel C is divided into 360 teeth, and must be kept clean by means of a brush passed over it every day in the direction of the length of its teeth.

"The horary circle, D, is divided into hours from six in the morning to six in the evening, then into parts of twenty minutes each, and lastly, into others of four minutes each, and is fixed on the axis by an hexagonal nut, which can be tightened by the hand. The index, E, slightly movable, serves to indicate the time on the horary circle, and has, for this object, a line engraved with a diamond on its upper part.

"The collar, I, works in a groove cut in the axis, A, and can be made one piece with the axis by tightening, or be left to turn freely about the axis by loosening the screw I, which must be handled gently, and never screwed up very tight. This collar terminates at its lower part in a rod, constantly pressed towards the letter J by a spiral spring. A screw, J, therefore, fixed in an arm-rest, which is attached to the immovable part of the heliostat, and which also carries the spiral spring, enables the collar to be moved in one direction or the other (and consequently the axis A, if the screw I is fast) by very small degrees at a time.

"The arm-rest, P Q, is of iron. At one end it carries a counterpoise, Q, which serves to balance it about the axis A; and at the other an index, P, and an adjusting screw, T U, of which we shall speak presently.

"The mirror, S R, is octagonal, of finely silvered glass. It is mounted in a frame of polished ebony, and has at its two extremities two pivots of polished brass of exactly the same diameter, and with their imaginary axis passing through the reflecting surface of the mirror, and at right angles to the index, X Z, and to the axis, A. These pivots revolve on the arm-rest, P Q, on Y-shaped bearings, and are kept in place by plates of brass.

"The declination-circle, P, is fixed on one of the pivots and divided into half degrees. When the zero of the graduation is brought opposite the index, the surface of the mirror is exactly perpendicular to the axis A—an adjustment made by the maker, and which must never be deranged in dismounting or shifting the index. In the position of the circle shown in Fig. 33, the circle must be read to the right of the zero in winter (from September 21 to March 21), and to the left of the zero in summer (from March 21 to September 21).

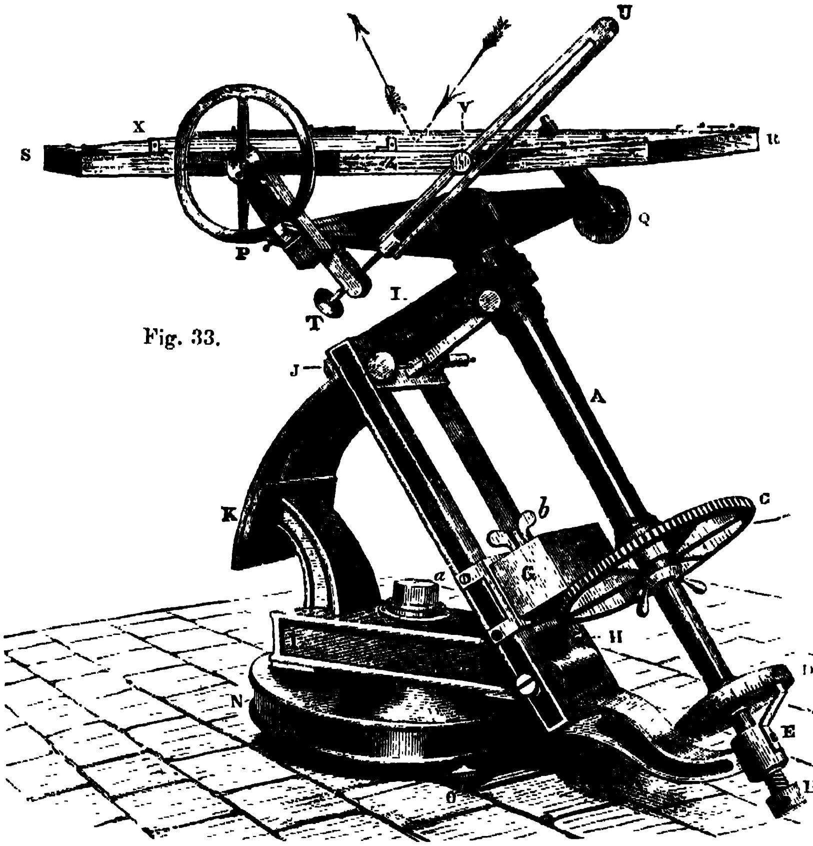


Fig. 33.

"The index is formed of a movable plate of brass, which can be applied to the division of the circle, or removed from it by pressing on the lower part. A single line traced on its upper surface serves to indicate the division of the declination-circle; and as the half and even the quarter of each of them, corresponding to ¼ or ⅛ of a degree (15 or 7½ minutes of an arc), can be very well estimated, this amply suffices for the adjustment of the instrument. It is necessary, however, to be well practised in reading the circle, or better still, to get assistance from some one accustomed to this kind of readings, which besides requires to be done but once for all.

"The bar, U T, consists of a slide-rod, capable of forming one piece with the mirror by tightening the screw V. An adjusting screw, T, attached to the arm P Q, allows, when the screw V is fast, of the mirror being moved very small distances at a time.

"The two sights, X, Z, are squares of brass plate, placed at the sides of the wooden mounting of the mirror, each being pierced by a small hole. Further, the sight X bears on its surface, facing the opposite sight, two lines perpendicular to each other, traced with a diamond, one being parallel to the surface of the mirror.

"When the sights, X, Z, are brought in a line with the sun, a thread of sunlight is seen proceeding from the aperture in the sight Z, and falling on that of the sight X, where it forms an image of the sun. In performing this operation we are guided by the shadow of the sight Z, which ought to fall parallel to the wooden mounting of the mirror. The hand should be held behind the sight X, in order to bring the shadow of the other sight more easily upon the first.

"The clock-work is enclosed in a brass box, G, and is wound up by the key *b*; it goes ten hours, and communicates its motion to the wheel C by its pinion H.

"The clock-work is fixed to the immovable part of the heliostat by four screws, but by slightly loosening the two inferior screws and lowering the clock-work, the pinion H is thrown out of gear. The pinion H can at pleasure be put in or thrown out of gear with the clock-work by tightening or opening the nut H. If it is unscrewed, the axis, A, can be slowly turned, and then the pinion is seen to revolve rapidly. If it is screwed up, the clock-work immediately acts on the toothed wheel C, so as to make it perform a complete revolution in twenty-four hours. Keep the open part of the box under the key, *b*, covered by a brass plate, to prevent dust from getting into the clock.

"*Management of the Heliostat.*—Wind up the clock-work, loosen the screws V, I, H, take hold of the mirror at R, and give it its proper direction, about which we shall speak presently; when this is very nearly effected, tighten the screws V and I, and adjust the mirror by the screws T and J to give it its correct position; then immediately close the nut H, and loosen the screw I, and the mirror will obey the clock-work.

"*Setting the Heliostat.*—Make the table, N, horizontal by means of the level; keep the screws *a*, V, I, and H loose, after having wound up the clock-work.

"Begin by rendering the mirror horizontal by applying the spirit-level to its surface in the direction X Z, tighten the screw V, and complete the adjustment with the screw T. Then applying the level to it in the direction of the pivots (and at right angles to X Z), tighten the screw I, and complete the adjustment with the screw J. Go through the two adjustments again, without loosening the screws V and I, making use of the screws T and J only.

"Having thus rendered the mirror quite horizontal, see if the line xii of the horary circle D is quite in juxtaposition with the line marked on the index E, and if it is not so, move the index and the circle D cautiously, so that these two lines become a prolongation one of the other, but without allowing the index E to touch the circle D, otherwise a displacement of this index might take place in turning the axis A. Now loosen the screws V and I.

"Find out from an astronomical almanack the declination of the sun on the day on which you are working, and, taking the mirror in the right hand at R, communicate to it such a motion as to very nearly bring the indicated degree of the circle P opposite the index. Tighten the screw V, and turn the screw T until the index exactly marks the declination of the sun at the time.

"Taking now the mirror in the hand at R, and noting on your watch the *true time*,* make the index indicate this time on the

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* "The *true* or *apparent time* is the time marked by the sun-dial, and not the time marked by the ordinary clock, which is *mean time*. The difference between the mean time and the true time constitutes the *equation of time*.

"To set a heliostat well, a knowledge of the exact time (to within a circle D, by communicating a rotatory motion to the axis A. When this is very nearly effected, let go the mirror and tighten the screw I. Then turn the entire instrument round on its pivot *a*—taking it by the screw B, and without stirring the table N—until you see the thread of solar rays emerging from the aperture of the sight Z, and falling on the centre of the sight X. Then tighten the screw *a*, and the heliostat is set.

"If now, in succession, you open the screw I, and close the screw H, you will see the image of the sun remain motionless for hours together at the centre of the sight X, and it is only when this is the case that the heliostat is accurately set. It must never be made use of until its working has been thus verified. When the heliostat is set, the table N and the pieces L M, K J, J M being left in position, all the other parts may be dismounted and taken away. To do this, open the nuts which hold the circles C and D; lower the clock-work; open the collar I, by removing the screws which close it round the axis; and open and remove the upper half of the bearing in which the upper part of the axis works. The mirror, the arm-rest, and the axis can then be removed, without the heliostat having to be re-set when they are replaced.

"There are three ways of setting up the heliostat in connection with other apparatus.

"1. The most simple consists in inclining the accessory apparatus so that its optical axis coincides with the axis of the heliostat.

"2. The second consists in rendering the reflected rays horizontal by means of a second mirror, and in any direction whatever.

"3. The third in rendering the reflected solar rays horizontal by a mirror inclined at 45° to the axis of the heliostat, in such a way as to reflect them from the east to the west, or from the west to the east."

The mutual adjustment of heliostat and apparatus employed is thus effected:—

Firstly, it is placed in a direction from south to north (the heliostat to the south), and in doing this the place of the sun at the true noon-time is the guide. Having levelled the heliostat, suspend a plumb-line in front of the combined apparatus, plunge its weight in a bucket of water to keep the line steady, and in such a position that the line stands but a short distance from the screw B of the heliostat. Having set a watch (as described in the previous foot-note) to the true time, at *the true noon time precisely*, move the entire instrument from left to right or from right to left, so that the shadow of the plumb-line divides the screw B, the circle D, the axis A, and the accessory apparatus into two exactly equal parts. The entire apparatus is then in adjustment if the image of the sun appears as a fixed spot.

SEATS OF INDUSTRY.—XVI.

NOTTINGHAM.

BY WILLIAM WATT WEBSTER.

On the banks of the Leen, about three-quarters of a mile from its junction with the Trent, stands Nottingham, the capital of Nottinghamshire, the chief seat of the bobbin-net and lace manufactures of England, and one of the principal centres of the English hosiery trade. This important manufacturing town occupies a very picturesque and romantic position near the south-western extremity of what was formerly Sherwood Forest, the head-quarters of Robin Hood and his band, but is now a cultivated district. It is built partly at the foot and partly on the broken and occasionally steep declivities of a red sandstone rock, rising 133 feet above the level of the surrounding meadows, and overlooking the valley of the Trent. The origin of the town is hid in obscurity, but it is believed that the site it occupies was a favourite resort of the Druids, and that the numerous caverns and vaults with which the rock is perforated were hollowed out by them. The Saxons called the place *Snotenagaham* or *Snottingaham*, and from this word, which signifies a retreat in rocks, the name Nottingham was doubtless derived. During the Saxon Heptarchy Nottingham belonged to the kingdom of Mercia; and after the Heptarchy terminated in 828 A.D., it was a Danish borough. In the reign of Ethelred I. there was a fortress on the rock; and in the time of his successor, Alfred the Great, the town had become of sufficient importance to give its name to the county. Ancient records mention that the Danes received a check from the town of Nottingham, and that they were defeated by Alfred in a great battle fought in the neighbourhood. Nottingham was first walled in by Edward the Elder in the beginning of the tenth century; and at the time of the Norman Conquest, as appears from the Domesday Survey, it contained 120 dwelling-houses. William Peveril, the natural son of William the Conqueror, built a castle on the summit of the rock, for the purpose, it is understood, of overawing and repressing the outlaws, who sought shelter in the old forest.

Nottingham claims to be a borough by prescription, but it received charters from Henry II., and many subsequent monarchs. Edward I., in the year 1284, granted it the privilege of sending two members to Parliament; and Henry VI. constituted the town a county by itself. In the reign of Edward III.—"the greatest of the Plantagenets"—several Parliaments sat at Nottingham, in one of which laws relating to the settlement of Flemish artisans in England were passed. During the Wars of the Roses Nottingham was the principal rendezvous for the troops of Edward IV. and Richard III., and it was from this town that the latter marched to the fatal battle of Bosworth Field. Charles I. selected Nottingham as the spot where he formally erected his standard against the Parliament; but the inhabitants of the town being warmly attached to the Republican cause, he was soon after compelled to evacuate the town and castle, which fell into the possession of the Parliamentary forces. Being attacked by the Royalists at a later period, the castle, gallantly defended by Colonel Hutchinson, a native of Nottingham, successfully resisted a prolonged and determined siege; but when the civil war was over, it was dismantled by the Protector. Subsequently it was pulled down; and in 1674, William Cavendish, Duke of Newcastle, erected on the site a mansion resembling a castle only in size and name, which was destroyed by a body of rioters in a disturbance that took place in 1831, ostensibly as a protest against the rejection of the Reform Bill by the House of Lords. Of the ancient castle only a few vestiges remain.

The modern industrial history of Nottingham may be said to date from the invention and introduction of the stocking-frame, which was adopted at nearly the same time by the manufacturers of Nottingham and Leicester. The art of weaving stockings out of worsted, silk, and other materials, was discovered in Scotland, and it was improved upon in France and Spain, before it came to be generally practised in England. Previous to this the stockings worn were simply tight-fitting trouser-legs or gaiters, with feet attached to them. A passage in Stubbes's "Anatomy of Abuses," published in 1596, enables us to fix the date when the knitted stocking began to supplant the cloth one. "They have nether-stocks," says the author of this work, referring to the fops of the period, "not of cloth, though never so fine, for

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minute) is indispensable, and should be carefully attended to. Throughout the United Kingdom, at all railway stations, Greenwich *mean* time is always adopted for civil convenience, although obviously that time does not truly indicate mean time in other localities situated east or west of Greenwich. In any place, therefore, where a heliostat is to be arranged for the day, it will be very easy to calculate the *true* or *apparent* time by the following data:—

"1. The exact longitude of the spot to within fifteen seconds must be accurately ascertained. This can easily be got from the Ordnance maps.

"2. Greenwich *mean* time must be known, and this, to within a few seconds, can be ascertained at the nearest railway station.

"3. An astronomical almanack (Dietrichsen and Hannay's is very convenient and cheap), containing the *equation of time*, *declination of the sun*, etc., for every day of the year, is required.

"With these data known, suppose it is wished to arrange a properly set-up heliostat at Liverpool for a day's work, say at nine o'clock on the 1st of October, 1867. The longitude of Liverpool is three degrees west of Greenwich; the *true* time at that place is, therefore, exactly twelve minutes later than London time. First ascertain accurately nine o'clock by Greenwich mean time, deduct from that twelve minutes for difference of west longitude, then turn to the almanack for the *equation of time* for that day, which happens to show *minus* ten minutes fourteen seconds. In other words, the sun is *faster*, or passes the meridian sooner than the mean time indicates. This difference must therefore be added to the *mean* in order to get the true time. Thus, 9 hrs. − 12 min. + 10 min. 14 sec. = 8 hrs. 58′ 14″, which is the time at which the horary circle of the heliostat is to be set for that day at Liverpool. And so for any other place, taking care, however, to note that a divergence from Greenwich time must be added when the place is east longitude, and that every 15′ of longitude is equivalent to one minute of time.

that is thought too base, but of worsted, silk, thread, and such like, or else, at the least, of the finest yarn that can be got, and so curiously knit, with open seam down the leg, with quirks and clocks about the ankles, and sometimes haply interlaced about the ankles with gold or silver threads, as is wonderful to behold. And to such impudent insolency and shameful outrage is it now grown, that every one almost, though otherwise very poor, having scarce forty shillings wages by the year, will not stick to have two or three pair of these silk nether-stocks, or else of the finest yarn that may be got, though the price of them be twenty shillings or more, as commonly it is. The time hath been," adds this enemy of luxury and expense, "when one might have clothed all his body well, from top to toe, for less than a pair of these nether-stocks will cost."

But an improvement had already been effected in the method of making knitted stockings that was destined to reduce the cost of their production, and bring them into universal use. Ten years before Stubbes denounced the luxury of "nether-stocks," William Lee, a native of Woodburgh in Nottinghamshire, and a graduate of St. John's College, Cambridge, was appointed curate of Calverton, a parish near the place of his birth; and in 1589, this country clergyman had in operation a stocking-frame, consisting of a row of knitting-needles kept going by a treadle, which produced stockings far more quickly than they could be woven by hand. Lee's machine has, of course, been greatly improved upon; but all the machinery now in use for the manufacture of knitted hosiery is worked upon the same principle. In connection with this important invention two romantic stories are told, which although not properly authenticated, may nevertheless contain some portion of truth. According to one of these accounts, Lee, while a student, courted a pretty country lass, who made her livelihood by knitting stockings. Being annoyed at finding her so engrossed in her occupation as to be unable to attend to his love-making, Lee sought some means of simplifying her labours, and securing her more leisure to walk and talk with him—the stocking-frame being the result. The other story is still more romantic, but not less probable. It is said that, after leaving college, Lee forfeited his fellowship by marrying the stocking-knitter, and that after he entered on his curacy, the wife found it necessary to continue her knitting in order to eke out the small stipend her husband received. Finding his wife toiling at the knitting-needles early and late, Lee was led to think over the process, and eventually discovered the principle of the stocking-frame with which his name is associated. The first machine invented by Lee was only suitable for knitting worsted, and it was not till 1598 that he succeeded in producing a frame delicate enough to make silk stockings. Although Lee's career as a stocking manufacturer hardly comes within the scope of this paper, it may be mentioned that about the year 1591 he threw up his curacy, carried his machine to London, and devoted himself wholly to its improvement, and to efforts to bring his invention into favour. Through the intercession of Lord Hunsdon, Queen Elizabeth was induced to visit the poor parson in Bunhill Fields, who had invented a wonderful contrivance for knitting stockings; but, while admiring the ingenuity of the machine, she refused to grant him a patent for his invention. In reply to a request for assistance from Lee's patron, Lord Hunsdon, Her Majesty is reported to have said, "I have too much love for my poor people who obtain their bread by the employment of knitting, to give my money to forward an invention that will tend to their ruin, by depriving them of employment, and thus make them beggars. Had Mr. Lee made a machine that would have made *silk* stockings, I should, I think, have been somewhat justified in granting him a patent for that monopoly, which would have affected only a small number of my subjects; but to enjoy the exclusive privilege of making stockings for the whole of my subjects, is too important to be granted to any individual." Lee carried on stocking manufacture for seven or eight years in Bunhill Fields, and had at one time nine machines in operation; but the expenses he incurred in perfecting his invention were greater than the profits he derived from the production of his frames, and he fell into such poverty and dejection, that he was almost induced to abandon the undertaking. In 1605, however, he went to France, on the invitation of Henri Quatre, and set up his machinery at Rouen; but after the assassination of his royal patron and protector, he wandered about from place to place, persecuted as an Englishman and a Protestant, and probably also as an inventor, until partly, if not wholly, through starvation and a broken heart, he died at Paris in 1610, just as his invention was coming to be generally accepted. Seven of his workmen in France returned to Nottingham, and entered the service of Aston, one of Lee's apprentices, who effected some improvements on his master's machine, and under Aston's management they laid the foundation of the stocking manufacture of England. In the time of the Commonwealth the stocking trade was so extensive, that the London stocking weavers sought to be incorporated in a guild, but it was not till 1663 that their wish was granted by Charles II. By the year 1670 there were 700 stocking-frames in operation in England; and in 1753 their number had risen to 14,000. In 1845 there were about 73,000 persons employed in the manufacture of stockings in Great Britain, and the quantity produced was reckoned to amount to upwards of 3,500,000 dozen pairs. At the present time it is estimated that nearly four-fifths of the stockings worn in the world are made in this country; and Nottinghamshire, and the adjoining counties of Leicester and Derby, are the districts where this trade is principally carried on.

The manufacture of a description of lace called bobbin-net has contributed to the prosperity of Nottingham in an almost equal degree with the stocking trade. The first attempts to manufacture lace by machinery were made as early as 1768; but although frequent efforts were subsequently made to shorten the tedious process of making lace on the pillow, no very great success was achieved till Mr. Heathcoat of Tiverton, in 1809, discovered and obtained a patent for his invention of the bobbin-net frame. Seven years later steam-power was first applied to this machine, and by 1822 or 1823 bobbin-net frames were generally driven by steam-engines. About the latter date the trade also received a great stimulus through the expiry of Heathcoat's patent. The quantity of bobbin-net lace produced increased enormously; the prices fell in consequence; and in a short time Nottingham lace to a great degree supplanted the pillow lace for which Flanders, France, and certain English counties were once highly celebrated. In the manufacture of plain nets Nottingham soon rivalled and surpassed all competitors; and the produce of the Nottingham bobbin-net frames was smuggled into those very countries from which lace had formerly been smuggled into England. In the early years of the trade plain nets alone were made, but after a time quillings were introduced, and at a later period figured or fancy patterns were produced. Quillings and figured patterns are the highest priced products of the bobbin-net frame, and these are the principal descriptions of lace goods manufactured in Nottingham. To show the rapid progress made in this industry, we may quote the account that Mr. Felkin gives of the trade in 1835, in his "History of the Machine-wrought Hosiery and Lace Manufactures." "In 1835," says the author of this standard work, "there were used in this apparently minute branch of industry, 1,850,000 lbs. of Sea Island cotton wool, valued at £185,000, and 25,000 lbs. of silk, valued at £40,000." The value of the produce of these raw materials and their disposal are stated to have been as follows:—"Home consumption for nets, £320,000; for quillings, £210,000; for fancies, £580,000—total, £1,110,000. Foreign trade, in nets, £340,000; in quillings, £282,000; in fancies, 480,000—total, £1,102,000. In the same year the plain nets sent from other parts of the kingdom to Nottingham to receive the finishing operations of gassing, bleaching, and dressing, were estimated at £328,000." A few years ago it was calculated that there were about 1,800 bobbin-net and warp-lace frames in operation in the town and neighbourhood of Nottingham.

In the early part of the present century Nottingham gained an unenviable notoriety in consequence of the frequency and violence of the riots that took place there. Among the most memorable of these were the riots of the Luddites, which were continued at intervals through a period of years. In 1811 great distress prevailed among the weavers of England, owing principally to the slackness of trade occasioned by the exclusion of British goods from foreign markets. The operatives, however, attributed their misery wholly to the spread of machinery; and combinations for the purpose of destroying the bobbin-net and stocking frames, which they supposed had deprived them of employment, were frequent in Nottingham. These riots were so well planned, and so destructive, and the rioters were so successful in escaping the vigilance of the police, that Parliament was eventually compelled to adopt special and very stringent measures for their suppression. An act declaring the wilful and malicious breaking of a stocking or lace frame to be a capital offence had to be passed before the Nottingham operatives abandoned their attempts to check the application of machinery to these manufactures by violent means. Many minor disturbances broke out in Nottingham between the Luddite riots and the outbreak to which we have already referred. These riots injured the trade of the town.

Nottingham enjoys considerable natural facilities and advantages for the successful prosecution of its manufactures and commerce. Coal is found in abundance at a distance of about two miles from the town; and there is a canal connecting the town northwards with the Codnor iron and coal district, and southwards with the Trent and the canal system of the northern midland counties. It need hardly be said that its railway communication is almost perfect. The Trent is navigable up to the point opposite Nottingham, and is there crossed by an ancient bridge, consisting of nineteen arches, and also by railway bridges. On the whole the town is but indifferently built, a large proportion of the streets being narrow and irregular, and in the older quarters of the town houses are to be found standing back to back without any interval between them. The houses for the most part are constructed of brick, and many of the streets rise above each other in successive terraces. One very crowded quarter, called the Marsh, lies about seventy feet below the prison, which is built on the edge of a rock. Extensive improvements have, however, been made in Nottingham during the past twenty years, many new streets having been constructed, and villas built in all directions. Formerly the burgess land formed a belt round the town of about a thousand acres, but this land was enclosed under the General Enclosure Act some twenty years ago, and since that time part of it has been built upon and part reserved for pleasure grounds, promenades, etc., eighteen acres of it being formed into an arboretum, to which the inhabitants have free access on three days of the week. The people of Nottingham also enjoy the use of a park of about 130 acres, belonging to the Duke of Newcastle. A striking contrast to the narrow streets of the town is afforded by the spacious market-place, which is a triangular area of five acres and a half, surrounded by lofty houses and shops with arcades. None of the public buildings of Nottingham possess any marked feature of interest or any remarkable history, except perhaps St. Mary's Church, an ancient Gothic structure, supposed to have been originally erected in the seventh century, but which has since been defaced by incongruous alterations in the Doric style. Among the institutions of the town may be mentioned the Free Grammar School, which was founded in 1513, but fell into disuse before the close of the last century, and was re-established and revived in 1807; the Blue Coat School, which clothes and educates sixty boys and twenty girls; the People's College, founded by subscription in 1846, to afford superior instruction to the working classes; and a National and a Lancastrian School.

In addition to the staple manufactures of Nottingham already mentioned, the town contains cotton, worsted, and silk mills; extensive establishments for the construction of bobbinnet and stocking-frame machinery; and large bleach-fields, malt-houses, and breweries. To illustrate the rapidity of the growth of Nottingham during the present century, the population returns may be cited. There were in Nottingham in 1801, 28,861 inhabitants; in 1811, 34,253; in 1821, 40,415; in 1831, 50,680; in 1851, 57,407; in 1861, 74,693; and in 1871, 86,608.

PRINCIPLES OF DESIGN.—XIX.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS (*continued*).

Pursuing our consideration of floor coverings, we may notice that a number of beautiful Indian carpets, such as we referred to in the last article, may be seen at the museum in the building of the new India Office at Whitehall, which museum is open free to the public (Figs. 66, 67, 68). There are also some good examples at the International Exhibition now open at South Kensington; but this exhibition is not of a permanent character. As to the nature of the pattern which may be applied to a carpet, we have "all-over" patterns, or patterns spreading regularly all over the surface; "geometrical" patterns, or those which have an apparent regularity of structure; and panel patterns, or those in which particular parts are, as it were, framed off from other parts.

First, as to "all-over" patterns. These are what we almost always find in both Indian and Persian carpets, and are, undoubtedly, the true form of decoration for a woven floor covering. What is desirable is an evenly spread pattern, such as will give richness without destroying the unity of the entire effect. The pattern may have parts slightly accentuated or emphasised beyond other parts, but not strongly so, and this emphasising of parts must be arranged with the view of securing to the pattern special interest. Thus, if a carpet is viewed at a distance it should not appear as devoid of all pattern, but through the slight predominance of certain leading features (in Indian carpets, generally of ornamental flowers) the plan of the design should be indicated. More detail should be apparent when the work is seen from a nearer point of view, and still more upon close inspection; but in no case should any parts appear strongly pronounced, or otherwise than refined and beautiful, and in no case should there be a want of interest manifested by the pattern.

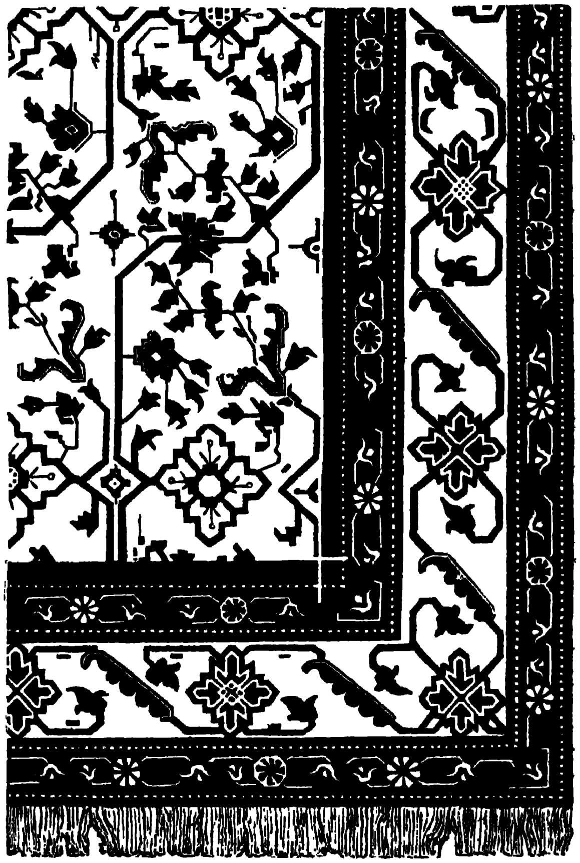


Fig. 67.

Carpet patterns are generally better if founded on a geometrical plan. In this way most of the Indian and Persian patterns are constructed. A geometrical plan secures to the design a manifestation of order and thought in its formation. Panel patterns, unless very carefully managed, become coarse. In some Indian carpets we find a sort of panel in which the colour of the ground is changed from that of the general ground of the carpet, but here the panel has usually a truly ornamental form, and is, indeed, rather a large ornament than a sort of frame enclosing a distinct space. Whenever a panel occurs in an Indian, Persian, or Moorish carpet, it is so managed, and its surroundings are such, as to cause it to appear as a part natural to the general design; but it is far otherwise with the panel patterns which we occasionally see in our shop-windows as the produce of native industry, and it is far otherwise with those which are used in vast quantities by the Americans. Judging from the carpets which they order, I imagine that nowhere on earth is taste in matters of decorative art so depraved as it is in America. It is true that the great floral patterns have ceased to be demanded by them, but they are only replaced by coarse, raw-looking, panel patterns, coloured in the most vulgar manner, and without even a hint at refinement or harmony of colour. Let the pattern be "loud" and inharmoniously coloured, and the chances of its sale in the American market are great.

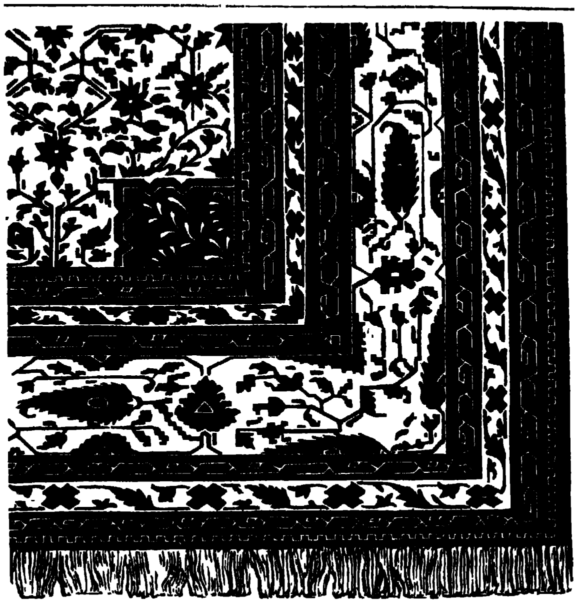


Fig. 68

But we must not forget that even in our own country bad patterns sell equally as well as good, inartistic patterns as well as those which are of a more refined character, and that even here in Great Britain more of the indifferent, if not of the very bad, sells than of the good. Let us cast the beam, then, from our own eye, before we try to extract it from that of another.

The ground colour of a carpet may vary much, as we all know; it may be black, blue, red, green, or white. If the ground of a carpet is pure white, it is almost impossible that it will look well. When I make this assertion I am often told that some of the Indian carpets which I so much admire have white grounds. This is a mistake. Some of them have light grounds, but not white grounds. They have light cream-grey grounds, or green-white grounds, but not pure white, and this tone of the ground altogether alters the case. Yet even with a light-toned ground it is not an easy matter to make a carpet which shall appear as a suitable background to the furniture of a room; it can be done, but it is a thing difficult to achieve. The safest and best ground for a carpet is black or indigo blue. If on this ground a closely fitting, well-studied pattern be arranged, drawn in small masses of bright colour, a beautiful bloomy effect may be achieved, and a glance at our best shop-windows will show that the most satisfactory carpets are coloured in this way.

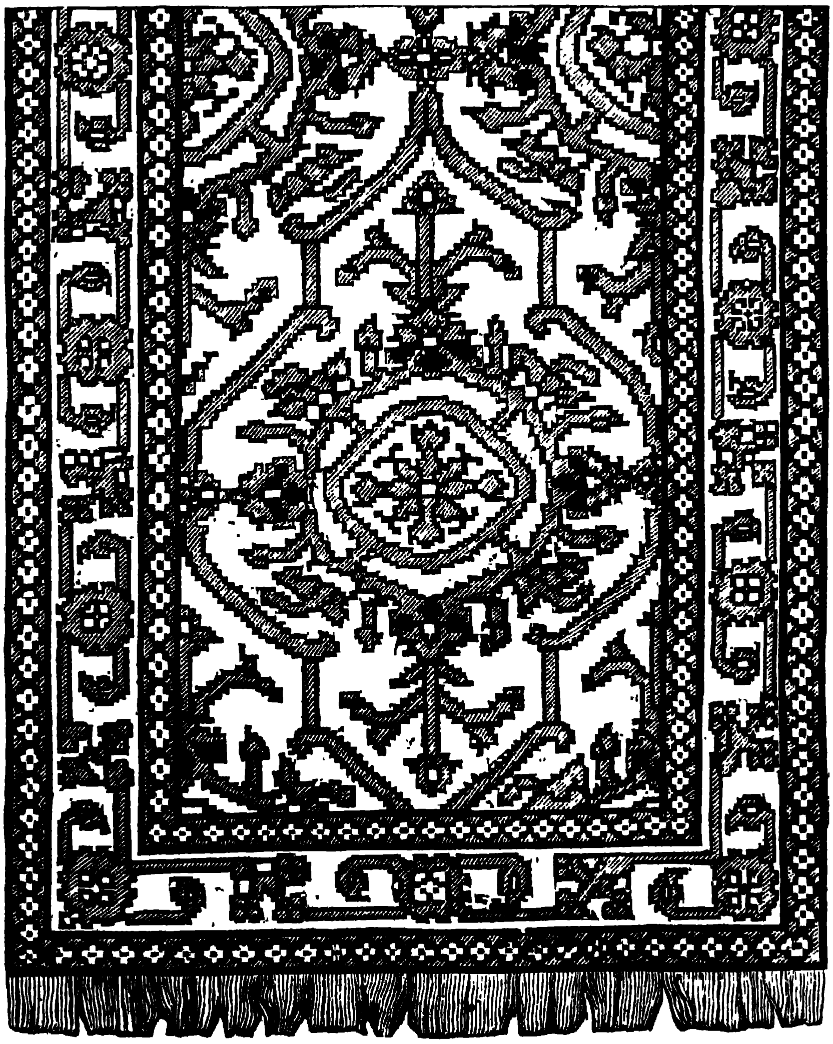


Fig. 66.

As to the size of the pattern we can say but little, as this will be determined by the coarseness or fineness of the fabric. In a Brussels carpet each stick is about the one-tenth of an inch square. In some Turkey carpets each stick is a quarter of an inch square. It is obvious that a much smaller and finer pattern can be produced in Brussels than in Turkey carpet.

A carpet pattern is best small, or at least small in detail if not in the extent of the design. A pattern may repeat three or four times in the width of the fabric (twenty-seven inches if Brussels), or but one figure may be shown, yet in this latter case the detail of the pattern may be as great as in the former. That degree of smallness which is compatible with tolerable distinctness of detail is desirable. For this reason Turkey carpets are not altogether satisfactory; no fine pattern can be worked in them, and besides this they have no colour-bloom and little colour-harmony. In some respects they are good, but altogether they are not satisfying.

Before I close these remarks upon carpets, let me say that, as designers, manufacturers, and consumers, we are one and all timid of new things. We want daring—the energy to produce new things, to manufacture them, to use them. What if the pattern is "extreme," if it is better than others? what if Mrs. Gamp should think us eccentric?—better be eccentric than ever harping on one monotony. If we could but bear calmly the derisive smiles of the ignorant, art-progress would be easy.

With us carpets cover the entire floor. In London these carpets are nailed to the boards, and but seldom taken up. In some parts of England we find rings sewn around the under edge of the carpet, which rings are looped to the heads of nails. Carpets so furnished can be more readily removed for cleaning than ours, which are nailed to the floor. Square carpets, such as the Turkey, Indian, and Persian, are spread loosely on the boards, and can be taken up and shaken without difficulty. This is unquestionably the healthy plan of using a carpet, and it is also an artistic plan. If the outer portion of the room floor is formed of inlaid wood of simple and suitable pattern, and a large loose square carpet is spread in the centre, we have an artistic effect, and the desirable knowledge that cleanliness is also attainable with a reasonable expenditure of labour.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVI.—THOMAS BEWICK, ENGRAVER.

BY JAMES GRANT.

THOMAS BEWICK, the reviver of the most useful art of wood-engraving in England, was born on the 11th of August, 1753, at Cherry-burn, about twelve miles westward from Newcastle, where his father rented a small land-sale colliery at Mick-lay-bank, near his residence, and in the pit thereof the future engraver worked in the coal seams when a boy. After a time, he was sent as a day-scholar to a school kept by the Rev. Mr. Gregson, at Ovingham, and as the parsonage in which his preceptor lived is prettily situated on a bank sloping downward to the Tyne, its locality seems early to have found pictorial interest in young Bewick's eye, as many reminiscences of it are to be found in his woodcuts, the gate being introduced with little variation in four different subjects; while in his tail-pieces are many other local memories of a similar kind.

English reading, writing, arithmetic, and a smattering of Latin, however, were all the acquirements the limited means of Bewick's father could procure him. Having early shown a decided taste for drawing, he was apprenticed by his father to Mr. Ralph Beilby, an engraver, living in Newcastle. This was on the 1st of October, 1767, and he was bound for a term of seven years; but it must be borne in mind that Beilby was not a wood-engraver, and his business in the copper-plate line allowed but little scope for artistic display. He engraved a few plates for obscure local books, when such chances came in his way; but his chief work lay in executing brass plates for doors, with the owners' names filled in with black sealing-wax, after the manner of the old *niellos*, so called from an old species of ornamental engraving resembling damask work; but of the art of wood-engraving, though long practised on the Continent, little or nothing was then known in England—at least, very little and humble were the efforts in that way. Types cut in wood were introduced at Strasburg by Guttenburg, so early as 1442; and in 1493, Wilhelm Pluydenwurff and Michael Wolgemuth, the first actual wood-engravers whose names are known, furnished in that year the folio plates for the Nuremburg Chronicle, containing figure subjects and views of towns. During the seventeenth century a few foreign engravers visited and worked in England, the most eminent being Crispin de Passe, Hollar, Dorigny, and others; but until the time of Faithorne the elder in 1670, our native engravers limited themselves to the production of maps and portraits, all of which were below even mediocrity. John Payne, an Englishman, first aspired to other cuts, and executed landscapes, flowers, and animals, etc., his chief print being the *Royal Sovereign*, man-of-war. Then followed the Whites, father and son, George Virtue (born 1684, died 1756), Woollet, Brown, Sir Robert Strange, and a few others.

Bewick's attention to the great value of wood-engraving was first drawn in consequence of his master having been employed by Dr. Charles Hutton, then a schoolmaster in Newcastle, to cut on wood the diagrams for his "Treatise on Mensuration," the printing of which was commenced in 1768, and took two years to complete. The cutting of these diagrams was committed by Mr. Beilby to young Bewick, who invented a graver with a fine groove at the point, thus enabling him to cut the outlines by a single operation. Ninepence per week was the sum then paid by young Bewick for his humble lodging in Newcastle, and weekly his mother sent him a large brown loaf, baked by herself in their home at Cherry-burn, whither he returned in October, 1774, on the expiration of his apprenticeship, but he still continued to work for Mr. Beilby.

Intending to apply himself now exclusively to the art and study of wood-engraving, he drew and executed several cuts as specimens of his power, and in 1775 he received a premium from the Society for the Encouragement of Arts and Manufactures, for a cut of the "Huntsman and the Old Hound," an oval print with a flowered border; and a fac-simile of this cut was used in the first collected edition of "Gay's Fables," printed at Newcastle by T. Saint in 1770.

Six years later found him making a tour, staff in hand, with a knapsack on his back, among the Cumberland lakes, when on a visit to some of his relations; and long after, in other days, he used to speak with admiration of the border mountain scenery, and "of the beauty of the white-washed and slate-covered cottages on the banks of some of those lakes." In a tail-piece to the first volume of his "British Birds," he introduces a sketch of himself, as he appeared on this tour, in his travelling costume, drinking from a wayside runnel out of the flap of his hat. After a brief visit to London, he became a partner with his old master, Beilby of Newcastle. He disliked the bustle of the metropolis, which he stigmatised as "a vast province covered with houses," and even advised his pupils to remain, when they could do so, in the country, and enjoy there the fresh air, the beauties of Nature, and of all things contentment.

"I am still of the same mind that I was when in London," he once wrote to his old schoolfellow Christopher Gregson, son of his former preceptor; "and that is, I would rather be herding sheep on Mick-lay-bank top than remain in London, though for doing so I was to be made the Premier of England!"

Bewick loved to spend all his hours of recreation in the open air, on his native Northumbrian hills, studying the characteristics of birds and beasts in their natural state, and noting those picturesque details of rural life which formed sketches and tail-pieces to his works. On the partnership with Beilby being fairly arranged, Bewick took as apprentice his younger brother John, who had been born in 1760; and though he assisted his partner in all the more mechanical parts of their business, he applied himself, whenever he could do so, exclusively to the art of wood-engraving. In addition to the cuts for "Gay's Fables" in 1779, he published an edition of "Select Fables," 1784, both printed by Saint; and in the latter he was assisted by his brother, as the title-page of the new octavo edition published at Newcastle, in 1820, bears "Select Fables, with cuts designed and engraved by Thomas and John Bewick and others, with a memoir and catalogue of their works."

In this work the animals are better drawn, the sketches more free, the backgrounds more natural, and the foliage fuller than in those for "Gay," showing that he improved as his art was exercised. "In the best cuts of the time of Durer and Holbein, the foliage is generally neglected; the artists of that period merely gave general forms to trees, without ever attending to that which contributes so much to their beauty. The merit of introducing this great improvement into wood-engraving, and of depicting quadrupeds and birds in their natural forms and with their characteristic expression, is undoubtedly due to Bewick."

Nine shillings each was the sum Bewick received for the cuts in the "Select Fables!" He was for five years engaged on his "General History of Quadrupeds," which was begun in 1785, and was published in 1790 by Robinson, Paternoster Row, in octavo, and the title-page announces the "figures engraved on wood by T. Bewick." His own account of the origin of this work may be quoted here:—

"From my first reading, when a boy at school, a sixpenny History of 'Birds and Beasts,' and then a wretched composition called the 'History of Three Hundred Animals,' to the time I became acquainted with works of natural history written for the perusal of men, I was never without the design of attempting something of this kind myself; but my principal object was, and still is, directed to the mental pleasure and improvement of youth; to engage their attention, to direct their steps aright, and to lead them on till they became enamoured of this innocent and delightful pursuit. Some time after my partnership with Mr. Beilby commenced, I communicated my wishes to him, and after many conversations he came into my plan of publishing a History of Quadrupeds, and I then immediately began to draw the animals, to design the vignettes, and to cut them on wood; and this, to avoid interruption, frequently till very late in the night; my partner at the same time undertaking to compile, and draw up the descriptions and history at his leisure hours, and in evenings at home. With the accounts of the foreign animals I did not much interfere; the sources whence I had drawn the little knowledge I possessed were open to my coadjutor, and he used them; but to those of the animals of our own country I lent a helping hand. This help was given in daily conversations, and in occasional notes and memoranda which were used in their proper places."

Of this work a second edition appeared in 1791, and a third in the following year at Newcastle. Some of the illustrations displayed a humour said by certain critics to be worthy of Hogarth, and as a specimen of this, one representing a sour-visaged old fellow in a three-cocked hat, conveying bags of corn to a mill on a lean, starved, over-laden, broken-kneed, and evidently string-halted horse, which he is beating with a stick, has been prominently selected. A hungry-looking dog goes in front towards a fence, beyond which, in distance, appears a farm gate and a square gallows, a feature frequently introduced by Bewick in sketches illustrative of knavery, malice, or cruelty.

Another sketch, as indicative of pathos, was selected by them—the "Ruined Cottage and Sheep." Near a hovel, of the roof of which three couple-poles, some thatch, and a chimney alone survive, "while all around is covered with snow, a lean and hungry ewe is seen nibbling at an old broom, while her young and weakly lamb is sucking her milkless teats. Such a picture of animal want, conceived with so much feeling and so well expressed, has, perhaps, never been represented by any artist except Bewick."*

Thus each of his illustrations was made, by its graphic power, to tell a story; and the success attending his work on Quadrupeds induced him to commence at once the designs and woodcuts for a "History of British Birds," the first volume of which was published in 1797; the simple, clear, and correct letterpress being, as in the former work, the production of his partner Mr. Beilby, with whom his partnership was dissolved in that year; hence the literary portions of the second volume, which appeared in 1804, were written by Bewick himself, but revised for the press by his friend, the Rev. Henry Cotes, Vicar of Bedlington, in the county of Durham.

The woodcuts of this work established, more than any of its predecessors, the fame of Bewick as a wood-engraver, and moreover as an artist; and nothing that has been produced since can be compared to them, nor shall they be equalled, says a writer, "till a designer and engraver shall arise, possessed of Bewick's knowledge of nature, and endowed with his happy talent for expressing it." He attained a skilful management of light and shade, which it is almost impossible to produce by means of copper-plate engraving.

An edition of his Quadrupeds appeared in two volumes in 1809, another in 1811; in 1818, he illustrated an octavo edition of "Æsop's Fables," with designs on wood, also published at Newcastle; and in 1821 appeared "A Supplement to the History of British Birds," in two parts, 8vo, at Newcastle.

Thomas Bewick diligently cultivated his inborn talents, and trusted neither to designers nor publishers for employment. He struck out a path and found employment for himself, seeking neither the directions nor the patronage of others; he thus preserved his independence, and was able to realise a competence together with no small share of worldly fame. Though his works were successful, he was never inattentive to self, and he frugally husbanded his earnings with an eye to provision in his old age.

In 1803, a portrait was painted of him by an artist named Murphy; but this he seems not to have had the vanity to engrave. On the 18th of April in that year, he gave the artist a letter of introduction to Mr. Christopher Gregson, the son of his old tutor before mentioned, then in London, and in this letter he pleasantly alludes to his own alleged beauty long ago when a boy.

"I do not imagine, my dear friend, that at your time of life you will be solicitous about forming new acquaintanceships; but it may not, perhaps, be putting you much out of the way to show any little civilities to Mr. Murphy during his stay in London.* He has, on his own account, taken my portrait, and I dare say will be desirous to show you it on the first opportunity; when you see it, you will no doubt conclude that T. B. is turning bonnier and bonnier in his old days; but, indeed, you cannot help knowing this, and also that there were great indications of its turning out so long since."

When health began to decline, and he lost much of his old energy of mind, the summer of 1828 found him again in London. He was then in his seventy-fifth year, and nothing that he saw could interest him; he longed for his native Tyne and the scenery of Northumberland. Even the objects in which he felt the greatest pleasure once were void of that for him now; hence, when one of his oldest and most valued friends drove him to the Regent's Park, he was either too feeble or too careless—at all events, he declined—to alight and to visit the animals in the Zoological Gardens.

On his return to Newcastle, somewhat of his former health, spirit, and tastes returned to him, but for a brief space only, and on the Saturday before his demise he took the block of "The Old Horse waiting for Death" to the printers, that he might have a proof of it struck off for him. On Monday after he fell ill, and when the proof came he had ceased to exist, closing his long and useful life at his house on the Windmill Hills of Gateshead above the Tyne, on the 8th of November, 1828. He was interred in the churchyard of Ovingham, of the parsonage of which he has left one of his most charming little woodcuts.

PRACTICAL PERSPECTIVE.—XIV.

In this lesson another study of polygons is given.

Fig. 69 is the plan of an octagonal plinth, on which rests an octagonal prism, of which the smaller figure is the plan.

The octagon is enclosed in a square, A B C D, and this is to be first projected as shown in previous lessons.

Proceeding then to Fig. 70, mark the points E and F between A and B, and lines drawn from them to the centre of the picture will cut the back line of the square in I and J.

Similarly, the points K and L being marked on the picture-line between A and C, and lines drawn from them to the point of distance will give the points K′ and L′ in the perspective side of the square, and from these horizontal lines across the figure will give the points G and H.

Join E F, F G, G H, H I, I J, J K′, K′ L′, and L′E, and the plan of the octagon will be completed.

Now raise perpendiculars from each of the angles of the square; mark on either of the front ones A or B, the true height of the plinth, and complete the upper surface of the square block *a b c d*.

From each of the angles of the octagon raise perpendiculars, cutting the upper square in the points *e*, *f*, *g*, *h*, *i*, *j*, *k*, and *l*.

Join these points, and thus complete the upper surface of the octagonal plinth.

The plan of the octagonal block might, of course, have been projected inside the original perspective plan; but it is advisable, for the sake of clearness, to defer it until this stage, so that it may be projected at once on the surface on which it is required.

To do this, produce the edge of the upper surface to C, equal to the distant side of the square. Between *a* and C set off *a* O and C P, corresponding with A T and C S in Fig. 69; from these points draw lines to the point of distance; and from the points where these lines cut the line drawn from A to C, draw horizontals.

Between *a* and *b* set off M and N, and from these points draw lines to the centre of the picture; these, cutting the two horizontals last drawn, will give the perspective view of the square in which the minor octagon is contained.

Between M and N set off U V, the width of the side of the smaller octagon; and these, cutting the front and back line of the inner square, will give the two sides *u v*, *y z*.

Now between *a* and C set off *a* W and C X, corresponding with A W′ and C X′ in Fig. 69, and draw lines to the point of distance, cutting *a c*; from these intersections draw horizontal lines, which, cutting M R in *w x*, will give another side of the octagon, the corresponding side to which will be obtained by drawing horizontals from *w* and *x* to cut N Q in *w′ x′*.

Join *v w′*, *w′ x′*, *x′ y*, and *z x*, *x w*, *w u*, and the smaller octagon will be completed.

Now, to project the top of the prism, at the required height draw the line A′ B′, corresponding with the side of the containing square, and on it set off the widths M′, N′, U′, V′ precisely over the points similarly lettered on the line *a b* below.

From M′, N′, U′, V′ draw lines to the centre of the picture, and from *u*, *v*, *w*, *w*,′ *x*, *x′*, *y*, and *z* draw perpendiculars to meet these. The points for the upper surface of the octagonal block will be thus obtained.

EXERCISE 66.

Put this object into perspective when standing at any distance (at pleasure) within the picture.

EXERCISE 67.

Scale ⅓ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

Subject, a hexagonal block of 3 feet side and 2 feet high, on which rests another hexagonal block, the side of which is 2 feet and the height of which is 8 feet.

Put this object into perspective when placed at 4 feet on the left of the spectator, the front of the lower block being on the picture-line.

EXERCISE 68.

Put the same object into perspective when another hexagonal block or slab rests on the top of it, precisely equal in size to the plinth on which the second block stands, but only half the height.

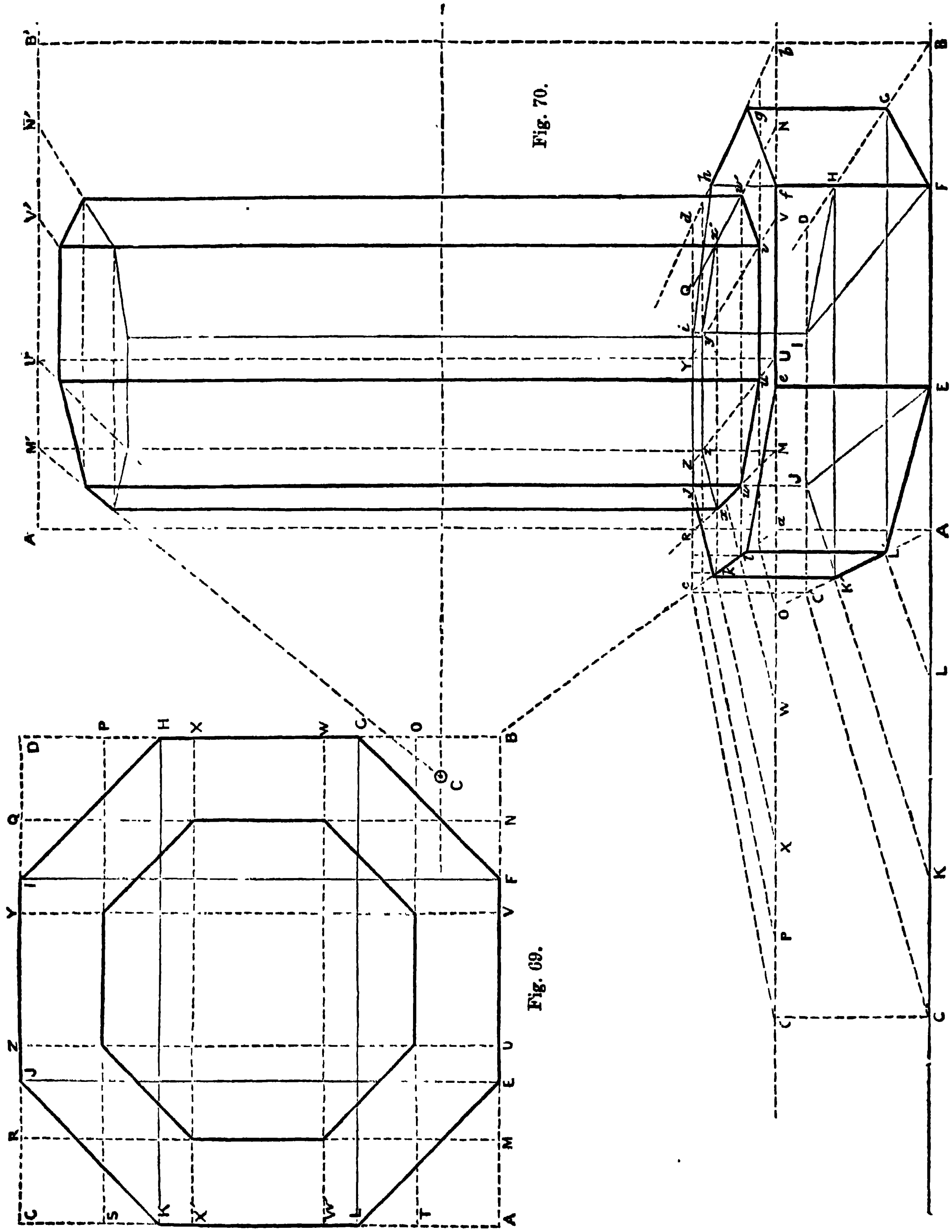


Fig. 70.

Fig. 69.

EXERCISE 69.

Put the same object into perspective when standing at 5 feet on the right of the spectator, at 6 feet within the picture.

EXERCISE 70.

Scale ½ inch to the foot. Height of spectator, 6 feet; distance, 15 feet.

Subject, an octagonal tube; side, 2 feet; length, 6 feet; thickness of material of which the tube is made, 6 inches (by scale).

Give a perspective view of this tube when lying at 4 feet on the left of the spectator, its end being at right angles to the picture-plane.

EXERCISE 71.

Put this same object into perspective when lying at 3 feet on the right of the spectator, and 8 feet within the picture.

EXERCISE 72.

Put the same tube into perspective when its octagonal end is vertical, and at 30° to the picture-plane, the nearest angle of the containing figure being on the picture-line at 3 feet on the left of the spectator.

EXERCISE 73.

Give a perspective view of this object when the long edges are at 30° to the picture-plane, and when it is situated at 5 feet on the right of the spectator, and 10 feet within the picture.

THE PERSPECTIVE OF CIRCLES.

To put circles and other curved forms into perspective, it is necessary that they should first be enclosed in the nearest rectilinear form which will contain them. In the case of circles this containing form will of course be a square.

Now let Fig. 71 be the circle which we require to put into perspective. Describe about it the square A B D C, and put the same into perspective at A (Fig. 72).

(It will be seen that the length of the side A B is not contained in this figure, nor is the point of distance. The student will, however, understand this elementary process.)

Now draw in Fig. 71 the two diameters E F and G H at right angles to each other, and project those in Fig. 72.

Draw the diagonals A D and B C, and insert these also in Fig. 72.

Now these diagonals cut the circle in the points M, O, N, P.

Through these points draw the lines I J, K L.

On the perpendicular A C in Fig. 72 mark off the heights I, K, and draw lines to the centre of the picture. These will cut the diagonals in the points M, O, N, P.

The perspective representation of the circle must now be traced by hand through the points E, M, H, O, F, P, G, N, E.

In the present study the circle is supposed to be the end of a cylinder, the length of which is represented by the distance from A to *a*.

At *a*, therefore, put the square into perspective, and draw the diameters *e f*, *g h*, and diagonals. Then horizontal lines drawn from the points M, N, O, P will cut the diagonals in the points *m*, *n*, *o*, *p*, and thus all the corresponding points will be obtained through which the curve is to be drawn.

The two ends are then to be united by the lines H *h* and G′ *g*. (The line Q R is called the axis, and this cylinder is spoken of as "having its axis parallel to the picture-plane.")

Fig. 71.

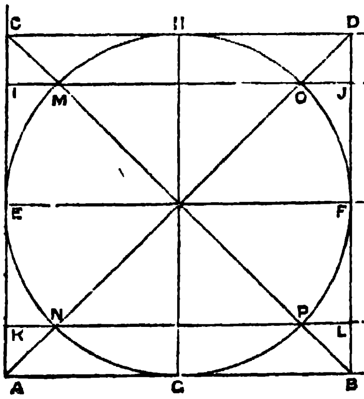
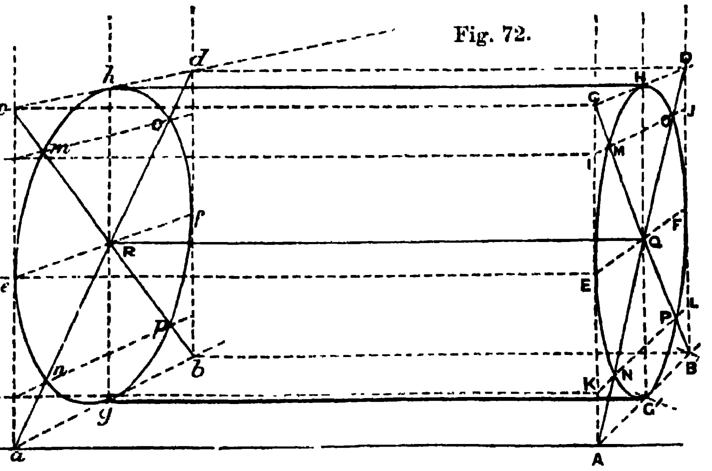


Fig. 72.



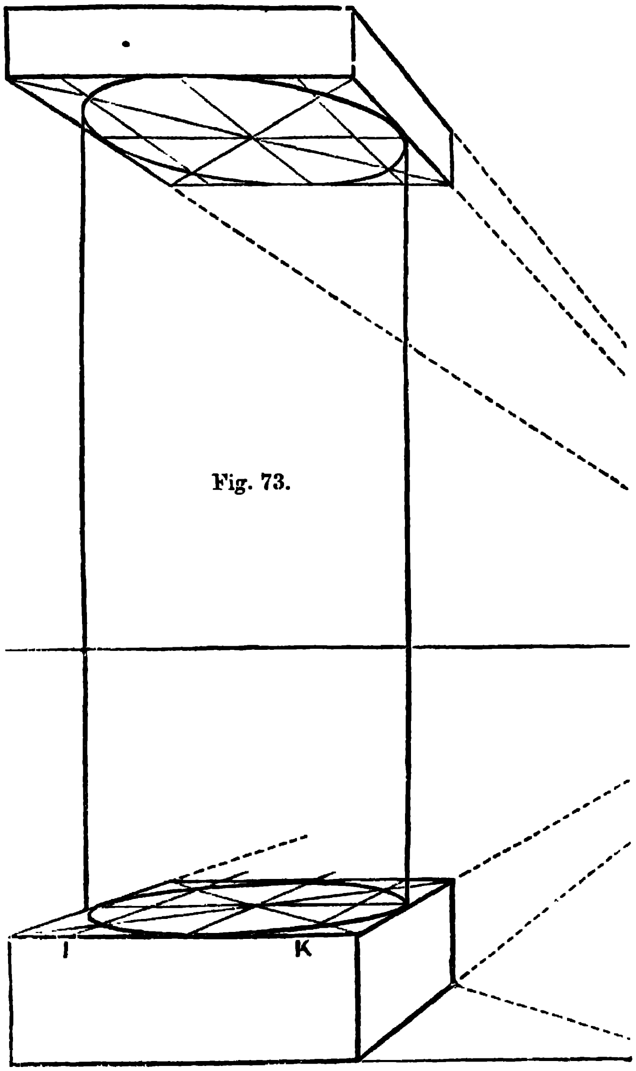


Fig. 73.

Fig. 73—This study is another application of the lesson given in Figs. 71 and 72, and represents a cylindrical column standing on a square base, and surmounted by a square slab.

Here the lower and upper blocks are completed first, and then the diameters and diagonals are drawn on the upper surface of the one and the under surface of the other.

The points I and K are measured from Fig. 71, the circle being the same size. From these points lines are drawn to the centre of the picture, and the necessary intersections obtained through which the curves are to be drawn, and these are afterwards united by vertical lines.

EXERCISE 74.

Put into perspective a cylinder when its axis is parallel to the picture-plane, its circular end at 4 feet on the right of the spectator, the object being placed at 8 feet within the picture.

The scale is ¼ inch to the foot, the height of the spectator is 6 feet, and the distance 15 feet. The diameter of the cylinder is 5 feet, and its length 6 feet.

EXERCISE 75.

Put the same cylinder into perspective when its axis is at 60° to the picture-plane, the object being situated in the immediate foreground, at 2 feet on the left of the spectator.

EXERCISE 76.

There is a row (four) of columns similar to that shown in Fig. 73. The following are the dimensions:—Width of plinth, 4 feet; height, 4 feet; width of upper slab, 4 feet; height, 6 inches; diameter of column, 4 feet; height, 12 feet. The distance between the columns is 8 feet. The scale is ½ inch to the foot. Height of spectator, 6 feet; distance, 18 feet.

Put into perspective two rows of columns as above, the one at 8 feet on the left, and the other 4 feet on the right of the spectator, both rows to recede at right angles to the plane of the picture.

EXERCISE 77.

Put into perspective the column shown in Fig. 73, when the sides of the base are at 40° and 50° to the plane of the picture, the rest of the conditions at pleasure.

SANITARY ENGINEERING.—VII.

COOKING BY GAS.

In continuation of our series of papers on gas manufacture, and the various means of its application and consumption, with a view to economy and otherwise, we now come to cooking by gas, a process we venture to think not generally understood, but none the less worthy of the serious attention of all classes of the community. Its great recommendation is economy and the absence of waste. When a kettle has to be boiled, or a chop to be cooked in the ordinary way, the fire has to be lighted, and to burn up to a certain point of heat before the kettle can be put on to boil, or the fire is sufficiently clear for the chop to be cooked; and here is at once a large element of waste, as the fuel consumed in getting the requisite amount of heat developed for the purpose required is all so much loss. When gas is used in cooking the case is different: the gas has only to be turned on and lighted—there is no fire to burn up; the requisite cooking temperature is immediately available—time and money, as we venture to think we can show in the sequel, are both saved.

Perhaps the simplest thing that has to be done in the way of cooking is the boiling of a kettle; and about the heaviest daily undertaking of a cooking nature the providing of the daily dinner of an immense asylum, containing about 1,000 inmates. We shall endeavour, as far as our limits will allow, to give as definite an idea as we can of how these very different results can be economically and satisfactorily carried out by gas, and gas alone. To begin at the begining. It has been ascertained by repeated experiments, into the detail of which our space does not allow us to go, that the most economical method of burning gas for cooking purposes is with a certain large admixture of atmospheric air, about 30 per cent., or perhaps a trifle more. *Light*, of course, the purpose for which gas is ordinarily used, is in this case of no account, the object being to develop the greatest amount of heat from the smallest consumption of gas, and the process is as follows. A No. 3 fish-tail burner, consuming say 3 feet per hour, is covered with a perforated copper bulb, about one inch or somewhat less in diameter; in the interior of the bulb the gas receives the necessary admixture of air, and when lighted outside burns with the peculiar blue, lambent flame engendered by the admixture. An apparatus of this kind, which can be used anywhere, only requiring its connection with gas, can be bought for three shillings; it will boil a pint of water in six minutes, and therefore the calculation stands as under—with gas at 3s. 6d. per thousand cubic feet, the average London price, the result being worked out by decimals, some trifle over one-tenth of a penny is the cost of the fuel consumed. In these small figures the comparison does not show economically in a striking form, but we venture to say that no housewife would undertake to light ten fires and boil ten kettles with a single pennyworth of fuel. We shall presently give some figures upon a larger scale, showing the absolute economy of cooking by gas.

We next come to the processes of toasting, roasting, broiling, and frying. These are conducted by reflected heat from a group or circle of burners arranged above the meat or other article that has to be cooked; and some most ingenious French apparatus has lately been introduced in which, by means of reflection from polished surfaces, very economical results have been obtained for every-day purposes. However, it may suffice to say that a gas-cooking apparatus can be purchased for from 15s. to 20s., in which a small joint or a pair of fowls can be roasted by reflected heat below the gas-ring or circle of burners, while above a kettle may be boiled, or vegetables, puddings, or similar matters placed above may be cooked by the same apparatus. And here let it be borne in mind that the waste of fuel in ordinary cooking does not arise only from the lighting of the fire; after the cooking is done the fire has to burn out, and therefore both before the cooking begins and after it is completed there is great waste of fuel and heat. When gas is used, when the cooking is done the gas is turned out at once, and thus only exactly the required amount of fuel is consumed.

We now come to a class of apparatus adapted for "family use," and here more elaborate arrangements are requisite. Sometimes they are simply constructed of iron, but recent improvements have introduced a lining of fire-clay, surrounded outside by some porous, non-conducting medium, which will allow the products of combustion to pass through, absorbing a portion of them, the remainder passing off either by a flue or directly into the external air, the whole being encased in a lining of sheet-iron, and provided with a movable lid, also protected by fire-clay. An apparatus of this sort, 3 feet high, 1 foot 8 inches in diameter, with a single gas-ring at the base, will cook 40 pounds of meat with a consumption of 50 feet of gas. The calculation of cost follows as a matter of course; and here we will give the record of an actual experiment, in which, however, only an ordinary apparatus was used, without the improvements just alluded to. A dinner consisting of mutton, beef-steaks, pork-pie, apple-pie, vegetables, etc., complete, the total weight somewhat exceeding 15 pounds, was cooked with a consumption of 75 feet of gas, at 5s. per thousand feet—the cost of fuel was 4½d.

In some recent experiments on a larger scale still more economical results have been arrived at; but perhaps the instance quoted is sufficient to establish the general principle, *i.e.* the economy of cooking by gas, the requisite facilities being first provided.

We now further proceed to describe a large cooking-range, as it may be termed, capable of turning out a dinner for 100 people—roasting, boiling, baking, frying—in fact, all the requisite processes of the kitchen. This will be 6 feet long, 3 feet high from the ground, and 2 feet deep from front to back—a very ordinary size for a common kitchen range; and the general frame is made of plates of cast-iron, of which we may take the average thickness at half an inch, put together in the ordinary way.

The upper surface is devoted to boiling, stewing, and similar purposes, and contains a number of gas-rings with their burners, or, as they are termed, open gas fires, upon which the various vessels are placed. These may vary in number according to the special requirements of the establishment—we may say from six to ten. In the centre, and rising in a semi-circular form above the level top of the stove, is a hot closet for warming plates, or similar purposes. Below the upper surface, with its open rings of fire, the space is divided into three; on the left is the roasting chamber, similar to that before described, which will cook several joints at once up to the weight of 50 pounds. In the centre is the broiling fire, arranged with a tray a small distance under a gas-ring, and occupying only a few inches in depth; this is large enough to cook say half-a-dozen chops at once, and may be described as the gridiron. Underneath this is an 8-gallon boiler for hot water, self-feeding, with subsidiary cistern and ball-cock specially provided for that purpose. The right of the three divisions is a pastry or bread-oven, large enough to bake about eight quartern loaves or a dozen of pies, the heat being regulated accordingly. What we have described is no theoretical or speculative arrangement; the details were taken from an apparatus we saw in daily work at a well-known public institution.

We may say that similar appliances are at work in many hotels and mansions throughout the country.

We now come to the last branch of our subject, the application of gas to the cooking the daily dinners required for a thousand inmates; and in this case we quote our particulars from an extensive set of the most improved kind which has been at work about six months at the London Hospital, Whitechapel. In this case the extent of the apparatus requires a separate provision for each particular process—the roasting, baking, and boiling—with the latter, however, the broiling is contained in one frame; and these different arrangements occupy one side of the large kitchen. On entering we first come to the ovens, two in number, each 6 feet high, 3 feet wide, and two feet deep, the gas-ring in each case running round the bottom, while a series of wrought-iron, light, movable shelves, commencing about 2 feet above the ring, extends to the upper part of the oven. Upon these the pies are placed, and each oven will bake fifty pies at one baking, the time varying, of course, with the nature of the dish, from a meat pie to a light pudding.

Next in order along the wall is the apparatus for boiling. The frame, somewhat similar to one just described, on a smaller scale, has fourteen open gas fires, varying from 8 inches diameter up to 12 inches, the larger openings containing a double ring of fire, one within the other. By the arrangement of the pipes and taps, either the inner or outer ring can be used separately, or they can both be used together. The size of the whole frame is 8 feet long, 2 feet wide, and 3 feet high.

Below these open fires another series of rings is arranged for broiling or frying. There is, of course, a horizontal division between the two, and under the second series of fires are arranged six trays, each 20 inches long and 12 inches wide, sliding in and out; each of these trays will cook 20 chops or thereabouts in a few minutes, will fry fish as required, or do any similar cookery.

Next adjoining is a roasting cupboard, about which we need not go into detail, as it is only used for casual purposes, and somewhat resembles that before described, with the exception of being in two heights, one above another, each 3 feet, with its separate gas-ring.

The series is completed by the great roasting apparatus, or roasting-well as it may be termed, as it is entirely below the floor-line, and covered with a large, hinged, iron cover, level with the floor, and raised by machinery specially designed for this object. The well itself is circular, 4 feet in internal diameter, cased round with fire-clay, and with an external lining of porous, non-conducting material; and into this well descends an open frame of light wrought-iron, upon which the meat to be roasted is arranged on horizontal spits. It will cook 500 pounds of meat in one operation, two hours being the time required, and the consumption of gas 250 feet. There is a large double gas-ring round the bottom; both rings are lighted when the roasting begins; when it has gone on for a certain time one of these is turned off, and the cooking finished with the other. When the meat is done the lid is wound up, and the frame lifted out bodily by means of a crane, the removal occupying but a few minutes. Beneath all is the dripping-pan (approached by a small iron staircase), and this has, of course, to be cleaned out after every roasting.

The entire cost of this large and complete cooking establishment may be roughly quoted at £1,000. We are unable to give any absolute experimental results as to the saving effected by it, as compared with the ordinary methods of cooking, because in this case it superseded an old-fashioned apparatus for cooking by gas already in use, in comparison with which, however, it effects a saving of £300 per annum in meat and gas, as proved by the printed reports of the hospital. Could the comparison be directly made, the results would, no doubt, be startling indeed.

We have thus endeavoured, as far as our limits will allow, to give a general idea of the methods adopted for cooking by gas, from the smallest to the most extensive scale. There are many manufacturers who make this class of apparatus their special study, and the number and variety of the applications of details are almost endless: many illustrated catalogues are published, showing how almost every class of apparatus can be most readily obtained. We have only been able to convey a general idea of the process, the use of which, however, recommended as it is by cleanliness, efficiency, and economy, is rapidly extending.

OBJECT DRAWING.—VII.

It is not deemed necessary here to give any further instructions as to shading. The application of the principles will be further shown in the figures which are to follow. The student is urged to think for himself; to place two or three blocks of wood in various positions, and by moving the light (or, if that be fixed, the models), so as to observe the varying effects of light and shade: the manipulative process is the result of practice, and this may be obtained by covering, at first, small surfaces, and subsequently larger ones, with flat tints of various degrees of darkness, and hatching them in vertical and horizontal directions. He must, however, bear in mind the axiom already laid down, that no amount of shading will remedy bad drawing, and that therefore by far greater importance must be attached to outlines than to shades. In all the lessons, therefore, the principles on which the outlines are based are fully given, so that this important point may not be lost sight of.

Fig. 41 represents two cubes, one of which is parallel to the picture, whilst the other is placed angularly, the upper one being surmounted by a pyramid composed of four equilateral triangles. Of course, the lower cube is to be sketched first, and in this view it has been so often drawn that it will not be necessary to give any instructions concerning it, and we will therefore proceed with our study of the upper objects.

It will be clear that, when the sides of a cube are at equal angles to the plane of the picture, the one diagonal of the base will be parallel, and the other at right angles to that plane. This will be understood by Fig. 42, which is the plan of two cubes, placed in the manner described, A B C D being the plan of the lower, and E G F H the plan of the upper. From this it will be seen—(1) that the diagonal G H of the upper cube is parallel to A D, the front edge of the lower one; (2) that the diagonal E F of the upper cube is at right angles to A D and B C of the lower cube, and therefore to the plane of the picture; and (3) that the intersection of the diagonals of the upper cube is in this position exactly on the intersection of the diagonals of the lower one, as if one axis penetrated the two. Therefore, let *a b c d* (Fig. 43) be the upper surface of the cube. Draw the diagonals *a c* and *d b*, and through their intersections draw *g h* parallel to *a d*, and *e f* in the direction of the point of sight, and projecting beyond *a d* and *b c*. From *e* draw lines to *g* and *h*, and produce them. From *g* and *h* draw lines converging towards *f*. This will be accomplished satisfactorily by making *h f* and *g f* rather shorter than *e g* and *e h*. This, then, will complete the plan of the upper cube, which is thus given in a separate figure in order to avoid confusion in the drawing.

Having brought the sketch (Fig. 41) up to this stage, draw the front edge of the upper cube, which, it must be remarked, must be slightly longer than the edges of the lower cube, since it is rather nearer the eye, being, in fact, the most prominent line in the picture. From the upper extremity of this line draw the edges convergent with the lower ones, and in the same manner draw the back edges of the cube. Draw diagonals, and at their intersection raise a perpendicular, on which mark the apex of the pyramid. Join this point to the angles of the cube, and thus complete the outline. Assuming that this has all been sketched in charcoal, and corrected with chalk (No. 1), the shading may now be proceeded with.

The shadow cast by the projecting angle of the upper cube on the front of the lower one may be rubbed in first; then the shaded side of each of the cubes, and of the pyramid. In this the student will observe the side of the upper cube not being as directly turned from the light as that of the lower (the first being at 45° and the latter at 90°), will not be so entirely prevented receiving light, and will therefore be rather lighter in shade than the other; whilst the side of the pyramid will be still less shaded, owing to the slanting of its surface.

The highest light of all will be at the front edge of the pyramid, and the side nearest the light; the brightest light being on the prominent edge of the cube, which similarly will gradually merge into the general tone of the whole side.

The triangular shape of the cast shadow is caused by the prominent angle of the cube, and the variation of this with the slightest alteration in position is exceedingly interesting to observe.

The group (Fig. 44) which will now form the subject of our remarks, is composed of a cube, on which stands an oblong block covered by the square pyramid.

The following are the proportions of the objects: the cube, 6-inch side; the oblong block, 4-inch side and 12 inches high; and the pyramid 4 inches square at its base. These are the sizes of the models on which these lessons are based, but of course any other proportions would do as well. It will thus be seen that when the oblong block stands on its end upon the cube, a margin is left, and the same width is also seen of the under surface of the base of the pyramid, which rests on and overhangs the oblong block.

The front edge of the cube, being the most prominent line, is, of course, to be drawn first, and the cube finished in the angular view as placed.

Now it is evident that since the sides of the two blocks are parallel, their diagonals will be coincident; that is, the diagonals of the base of the oblong block will rest exactly on those of the surface of the cube, but they will not equal them in length.

Having, then, completed the cube, draw diagonals in the upper surface, mark off on the diagonal which crosses from the most prominent angle the apparent distance of the angle of the upright block, and from this point draw lines to the vanishing-points of the edges of the cube, or at least convergent with them, so that, if produced, they would meet; for as the student advances, he is not expected, in hand-drawing, to really fix the vanishing-points, and rule the lines. A knowledge of the principles and observation of appearances will enable him to draw from objects with tolerable correctness, but, as said before, model-drawing is not intended to serve as a substitute for the study of perspective, but as an application by eye and hand of previously acquired rules, which have been accurately and carefully worked out: even as writing a letter or other composition is an application of the rules of grammar to which we have become so habituated that correctness comes almost by intuition.

These lines, then, tending to the vanishing-points, are to be drawn until they cut the diagonal which extends horizontally across the cube; and from these points lines drawn in the opposite direction will meet on the first diagonals and complete the base of the upright block.

In the present position of the cube, the one diagonal is horizontal, whilst the other, being at right angles to the plane of the picture, is drawn to the point of sight. As already explained, this is because the object is placed at equal angles, but would not be the case if it were in the slightest degree rotated.

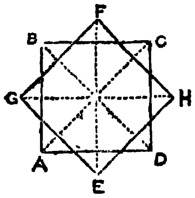


Fig. 42.

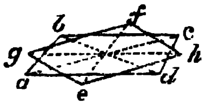


Fig. 43.

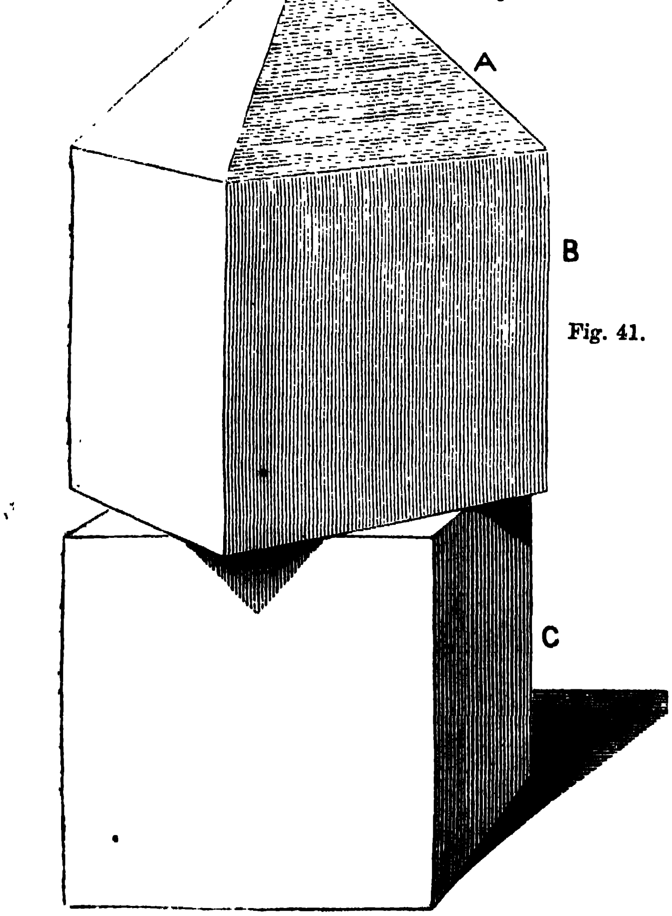


Fig. 41.

Proceed now to draw the perpendicular edge of the oblong block which is nearest the eye, and having fixed its apparent height, draw lines to the vanishing-points for the horizontal edges. In the present study the objects are placed so that the level of the eye is about the middle of the height of the group; whilst, therefore, the lines of the cube and the base of the oblong block tend upward, those of the top of the block and of the base of the pyramid incline downward.

Now from the left and right angles of the base draw perpendiculars for the two other visible edges of the object, and from the fourth angle draw a perpendicular which will be terminated by lines drawn to the vanishing-points from the extremities of the perpendiculars.

The inner surface of the top of the object will thus be represented. Of course, this would not be visible unless the model were transparent; but, as said before, it is best in the first sketch to assume this, in order to account for lines which are not visible, and to find the places for others which depend on them.

Through the distant and near angles of this inner surface draw a diagonal and produce it, remembering that, as the pyramid is exactly over the cube, the diagonals will be over each other, and therefore this one will converge to the point of sight —as does that of the cube—and the other diagonal will be horizontal, as already explained.

On the first diagonal mark the most prominent angle of the base of the pyramid, which will, of course, be exactly over the front angle of the cube. From this point draw lines to the vanishing-points, cutting the horizontal diagonal in points which will give the angles of the base, both of which again will be over the corresponding angles of the cube. From these points lines drawn to the opposite vanishing-points will give the back lines of the base of the pyramid which are in the view only partially visible.

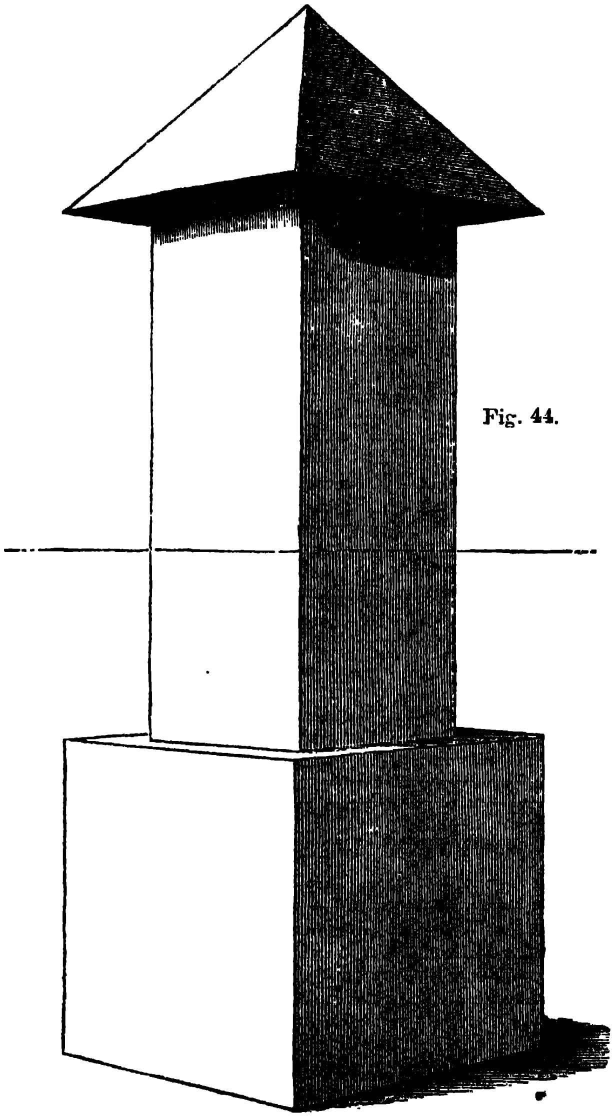


Fig. 44.

The apex of the pyramid will, of course, be situated on a perpendicular raised on the intersection of the diagonals. It is advisable, in order to test the exactness of subjects such as this, to sketch the inner surface of the base and draw diagonals, then a line passing through the intersections of each set of diagonals should be an absolutely *vertical* line—the axis, in fact, of the whole group.

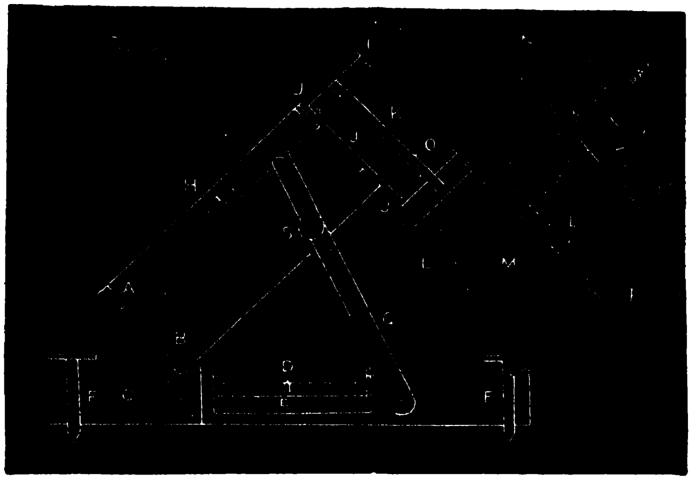
The method of shading this object will be given in the next lesson.

OPTICAL INSTRUMENTS.—XII.

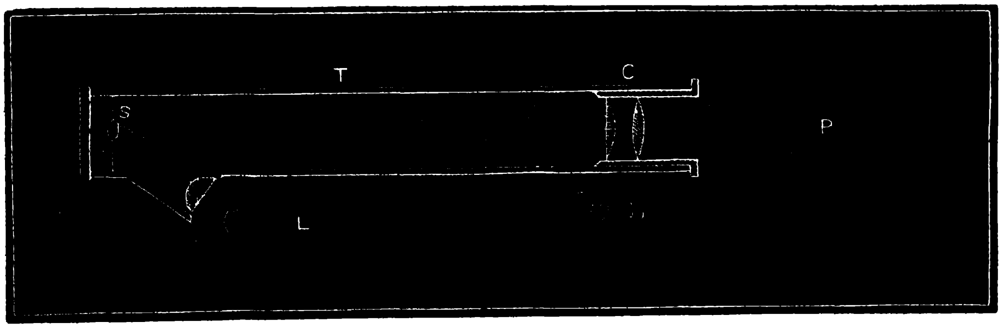
BY SAMUEL HIGHLEY, F.G.S., ETC.

SOURCES OF LIGHT.

Maddox's Heliostat is the simplest in construction, and meets every requirement where a small stationary beam of light is required. It consists of a stout base board surfaced with metal, C (Fig. 34), 5½ by 9, by 1⅜ inches thick, supported on three levelling-screws, F. In the centre of this base board a circular well is sunk in which is fitted a circular levelling box, E, and a compass-box having a 2½-inch needle, D; no iron must be used in the base board. To the upper surface a stout zinc box, A, about 5 inches square, and deep enough to hold an American ship's clock, is hinged at B. This box is set to any angle—to suit the latitude of the place in which the heliostat is set up—by means of two slotted struts, G, hinged at B, to the base, bound by pivots, and fixed to the side of the clock-box by clamp-screws S, working through the slots. A piece of brass with two projecting arms, J J, *set exactly at right angles* to the face of the box, supports the "polar axis," K, which is kept in place by a steel pin passing through a hole in the upper arm, and by two small bevelled friction-wheels, O, resting on the upper surface of the lower arm, through which the axis smoothly works. To the lower end of the axis is attached an oblong metal frame, L L, that carries the reflecting mirror M (the back of which is represented): one arm of this mirror-frame is longer than the other, and terminates in a small cubical box, P, for adjusting the reflector (according to the method of Dr. Curtis, U.S.A.), which is hinged so that it can be placed in front of the side of the mirror, or turned out of the way when the adjustment is completed. The length of the axis and frame depends upon the length of the mirror, but it need not necessarily exceed twelve inches from the upper support to the end of the cubical box.



The polar axis is rotated by means of an endless band passing over a grooved wheel, H, fixed on the axis of the hour-hand of the clock (from which the hands have been removed) and another grooved wheel, I, twice the size of the former, fixed on the axis, K, two holes being pierced in the clock-box to allow the passage of the endless band. The polar axis makes a revolution once in twenty-four hours. If desired, the wheel H may have a dial plate on its upper surface divided into twenty-four hours, and numbered from 12 above to 12 below, for the purpose of setting the instrument to time, the reading being taken from an index screwed to the face of the clock.



The mirror may also be set by means of a graduated arc fitted to its axis, to obtain adjustment for declination. The index-line is engraved on the arm of the mirror-frame. The zero point on the arc should be taken at 45° from the diameter of the arc that passes through the plane of the mirror's surface. The arc is graduated into half-degrees, for 24 half-degrees to each side of the zero-line; each half-degree being numbered 1, 2, 3, etc., counting each way from the zero-line, so that each half-degree to the left or right of the zero-line gives the necessary adjustment of the mirror for each whole degree of the sun's declination north or south respectively. To make the adjustment, turn the mirror until the index points to the number on the graduated arc which represents the actual degree of declination of the sun for the given day.

These complications are, under ordinary circumstances, rendered unnecessary by employing *Curtis's Heliostat Adjuster*, which is thus described by its inventor:—

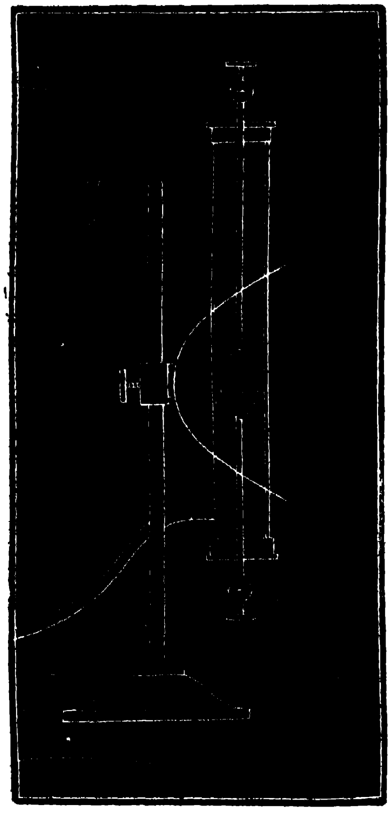
P′ gives a perspective view of the cubical box; N shows the arm of the mirror-support to which it is hinged, furnished with a projecting knee, to prevent the box from turning too far back upon the hinge. In the face of this box which fronts to the sun, is a fine slot, running exactly north and south, and upon the under-face is a corresponding slot or line. Then to set the heliostat for time, it is only necessary to rotate the polar rod until the fine ray of sunlight passing through the slot in the upper face falls exactly on the line on the under-face. In a similar manner the side which is turned towards the surface of the mirror has a fine slot cut through it in a direction at right angles to that of the other slot, and upon the opposing surface is a corresponding slot or line. Since these two slots lie in the direction of the polar axis, it is only necessary, in order to set the mirror for declination, to turn it until the reflected beam from its surface which passes through the slot in the side falls exactly upon the indicator slot in the opposite side. After the adjustments are made, the little box may be turned up on its hinges, so as to rest against the supporting arm, and leave the reflected beam from the mirror unobstructed. The dotted lines show the directions of the direct and reflected rays when the adjustments are corrected.

ARTIFICIAL SOURCES OF LIGHT.

Many heads have been at work within the last few years, trying to discover new compounds, arrangements, and forms of lamps that will give the greatest amount of light with the least amount of trouble and discomfort in preparation, to meet the requirements of lecturers and amateurs who only require a lamp for occasional use, or for those who are nervous as to employing the most powerful light-giving apparatus; others have been trying to obtain still greater power out of the oxy-hydrogen jet, and simpler or safer ways of manipulation; and a few to secure the most intense light attainable by man, that should even out-rival and render him independent of the sun as a source of light, whose face is too often hidden in this our moist and cloudy clime of England, when we most want his assistance. In this bold aspiration—almost as daring in thought as that of the builders of Babel—Wilde has been successful; for, from a pair of carbon points, half an inch square, placed on the top of a lofty building, the light evolved from his magneto-electric machine was sufficient to cast the shadows of the flame of street lamps a quarter of a mile distant, upon a neighbouring wall; while at noon, on a clear day in the month of March, the direct rays of the sun took *one* minute to darken a piece of sensitive photographic paper, the light emitted at two feet from the reflector of this electric light darkened it to an equal degree in 20 *seconds;* and on a day in June, Mr. Crookes estimated that this electric light had three or four times the luminous and calorific power of the sun at mid-day, at a cost of only a halfpenny per hour, practical not theoretical value, for the driving power of this giant induction machine of Mr. Wilde's invention.

Mr. Crookes further remarks that, "It would be an interesting problem to calculate what would be the result of driving the 32-inch armature required for a 100-ton magnet, with (say) a 1,000 horse-power steam-engine. If the power generated by this machine did not at once burn up the working parts, dissipate the electric lamp and conducting wires with a mighty explosion into space, and strike dead all the attendants with one lightning flash—if it were at all manageable, and were put on a high tower, it would probably give light enough to make London by night considerably brighter than London by day." *

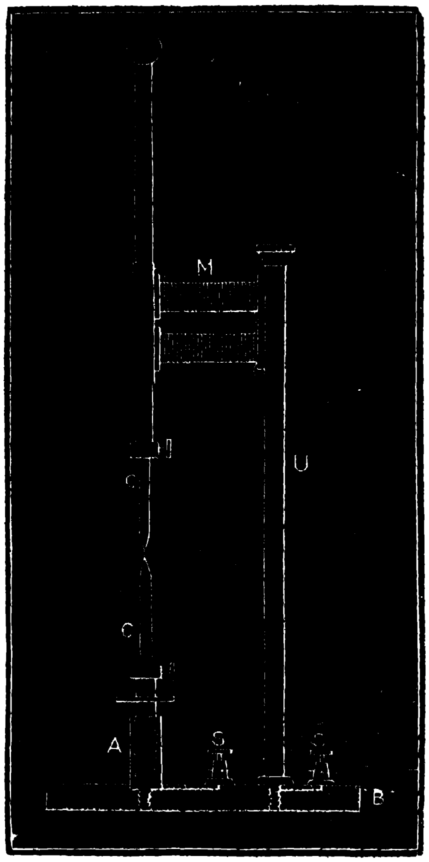
Artificial Star.—The optician employs the sun, the moon, or a star for "adjusting" spectroscopes and other instruments. As these are not always accessible at the moment wanted, an artificial means of obtaining parallel rays for such a purpose is very desirable, and is attainable by an arrangement devised by Mr. Heisch. It consists of a bead of platinum, S (Fig. 35), made by fusing a bit of fine wire with an oxy-hydrogen blow-pipe, which yields a smooth, bright metallic surface, admirably adapted for reflecting a bright point of light. This is bedded in a cork, painted dead black, fitted into a brass cap, that slides into T, a tube about 8¼ inches long. To the side of this tube, a little lamp, similar to that represented in Fig. 13, page 156, is fitted by a smaller diagonal tube, so that its light may be concentrated on the bead S. At the other end of the tube a little condenser, C, is fitted, composed of a plano-convex and a double-convex lens, the combined focus of which equals 3 inches; this is focussed on the illuminated bead till any irregularity of surface is detectable either by a normal eye, or when examined by a telescope that has previously been set to the focus of a real star; the arrangement then yields parallel rays, and may be treated as a real star, and be employed as a star is for optical adjustments. This artificial star would be of great use to the spectacle-maker, as a means for focussing his glasses, which I omitted to mention in my previous article on spectacles.



THE ELECTRIC LIGHT.

The electric light may be regarded under three heads—namely, "the vacuum system," "the contact system," and "the arc system," to prevent confusion of ideas as to what *the* electric light proper really is.

The *vacuum light* I mention more as a suggestion for future elaboration, and as suitable for special experimental requirements, when a *moderately brilliant disc of light* can be brought into play without much trouble, by simply lowering the plates of a battery into the exciting solution by means of a windlass, the battery in such case being a "calorimeter" or "quantity arrangement," Smee's being the cleanest and most convenient for this purpose, though the bichromate carbon battery, with an arrangement for pumping air into the bottom of the solution, may be employed. The vacuum light consists of a platinum wire twisted in zig-zag so as to occupy a disc of the required size; the ends are riveted into two stout copper wires that pass through two brass caps and then terminate in binding-screws. The caps are cemented to the ends of a glass tube, that encloses the disc, and is supported in a parabolic mirror, so that the disc stands in the focus of the paraboloid, which in turn is supported on an adjusting rod. To one of the caps a tube is fitted, so that it can be connected with a good air-pump, that the tube may be simply exhausted, or a vacuum of any given gas produced, when a special tint of light is required, or for urging a column of air or oxygen through the tube, according to the nature of the light required. The arrangement is shown in Fig. 36. On the calorimeter being lowered, the resistance offered by the platinum causes the wire to glow, even to the melting-point, and though the turns of the wire do not touch, still, from the property of incandescent wires to appear of increased bulk, the disc looks like a solid mass of light.



Contact Light.—Of late years we have heard of "an electric regulator," worked with *six* cells, which, it is alleged, will produce a beam that supersedes the lime-light. Now as a regulator in no way adds to the battery power—and we have been accustomed to use from twenty to sixty cells for the production of the recognised amount of light—to those who have not been accustomed to get a quart of wine out of a pint bottle, this is rather a startling announcement, especially when we are told that a nine-feet disc can be brilliantly illuminated by this small number of cells. The battery power being so small, it is necessary to keep a pair of very fine-pointed carbon poles touching each other, to produce a small vivid point of light or "voltaic spark," so that we may call this "the contact system" in contradistinction to the arc-producing method, where the carbon poles are pulled apart to produce the "voltaic arc."

A contact-regulator may be thus typified:—An upright, U, attached to a base board, B (Fig. 37), carries an electro-magnet, M, to the poles of which an iron tube is fitted; through this a round polished iron rod smoothly fits, that carries the upper carbon, C, which *rests* on the lower carbon, C'. The lower carbon C' is clamped by a screw into a socket that is adjustable by a screw fitting A. Both A and M are connected by wires with their respective binding-screws, S, S. When the poles are connected with the terminals of a Grove or Bunsen's battery of six or seven cells arranged for intensity, the current passes through the wire of the electro-magnet M, magnetises the iron tube (which, acting on the iron rod, holds it firm), and then passing through the carbons, causes them to emit a bright electric spark, that continues as long as the points are in contact, for if they burn away so as to leave a space between them, a distance would soon be arrived at, over which the current could not, for want of sufficient power, jump, and the light would be extinguished. The exact point at which the current will pass and the light continue, is termed "the striking distance." To provide for this point not being overstepped, the magnet comes into play, for when the power of the current is weakened by an intervening space existing between the carbon points, the power of the electro-magnet consequently becomes proportionately weakened, and so, losing hold of the iron rod, allows it to slide till the upper carbon again rests upon the lower, and thus re-establishes the intensity of the light and magnetic power also. If more than six cells are used, the carbons may be separated after contact, in proportion to the number of cells employed, by means of the adjustment.

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* See "A New Era in Illumination,' by W. Crookes, F.R.S. (*Quarterly Journal of Science*, October, 1866.)

This, however, requires careful watching and manipulation of the adjustment, or the light will be constantly extinguished. In a limited sense such contact arrangements are automatic, but, as a rule, hand-adjusting regulators are more convenient and trustworthy at an equal cost of apparatus, especially if required for lantern demonstrations and spectrum experiments.

SANITARY ENGINEERING.—VIII.

ON VARIOUS APPLIANCES OF GAS TO DOMESTIC AND COMMERCIAL PURPOSES.

GAS BATHS, OR BATHS HEATED BY GAS.

THERE are many advantages in heating baths by gas—cleanliness, as there is no coal-fire, smoke, or ashes; convenience, as the gas can be lighted at any moment, and therefore the bath is at once available; and economy, as we shall proceed to show.

The simplest and perhaps most usual form of gas bath has a small cistern, holding a few gallons, communicating by two pipes of considerable size with the body of water in the bath, the quantity of water required being about forty to fifty gallons. The bath must be first filled with water to about the level of the upper pipe before the gas is lighted. An ingenious arrangement has been made, by which the double ring of burners or jets beneath the boiler, and just at the level of the floor, may be hinged, so as to swing out clear of the cistern, for convenience of lighting, and then returned to its place. The heated water from the top of the small boiler passes off through the upper pipe into the bath, the cooler water returning to the boiler by the lower pipe, a complete circulation being thus established. It has been proved by calculation — the gas being burnt by meter - that forty gallons of water may be heated to 100° Fahrenheit at a cost of twopence. The objections are that it is always necessary that the bath should be full, or nearly so before the gas is lighted, and that a very considerable amount of steam is evolved during the process, indicating a certain waste of heat, besides entailing by its presence some amount of actual inconvenience.

To obviate these difficulties several inventions have lately been brought out for heating the water to the requisite temperature by circulation through metal heated surfaces, so that it may be discharged into the bath at once at the temperature required. In these cases the filling of the bath is a gradual process, regulated by the apparatus employed and the temperature of the atmosphere at the time. Our space does not allow us to describe the mechanical particulars of the methods in use, but in some future papers on heating by hot water we may probably go more into detail.

It should, however, always be borne in mind that it is important that the products of gas combustion should never be allowed to mingle with the water, as in that case they are absorbed in considerable quantities; and in some instances the sulphurous acid will impart a distinct flavour to the water. A further advantage of gas baths is that they may be made perfectly portable, and in houses not provided with the necessary convenience, if the gas is only laid on by a flexible tube a warm bath may readily be obtained in about half an hour.

PATENT GAS FLOATS, FOR THEATRICAL PURPOSES.

The use of gas at the foot-lights has for many years obtained in our theatres, but has always hitherto been attended with a certain amount of danger. The draught of a passing dress has sometimes been sufficient to produce a flare of the gas, the dress has caught fire, and serious accidents have been the result. In like manner a glass will sometimes suddenly break, without warning, and any one who has seen the rush made to turn out the gas will readily appreciate the apprehension to which such an accident gives rise. Within the last few years, however, an invention has been introduced which materially modifies, if it does not entirely remove, all these sources of danger and inconvenience.

The range of Argand burners composing the float are arranged upside down, a wrought-iron flue being provided, into which the products of combustion are received and conducted to a special upcast flue, provided for the purpose in the construction of the building. To set the draught fairly in motion a small burner is provided in this shaft, which must be lighted some little time before the burners of the float, to create an updraught; and when this is fairly set going, curious to say, the burners are as efficient burning downwards as when lighted upwards in the ordinary way. Each burner is hinged to a tap, and supported in its position by the glass alone, which surrounds its own special opening in the wrought-iron flue. When a glass breaks under this system, the burner falls by its own weight, turning itself out by the motion, and all risk is thus avoided. It is usual to provide, a few inches above the bottom—which in this case occupies the position of the top of the burner—a covering sheet of thin wrought iron as a further protection; and so thoroughly is security obtained, that upon this sheet of iron, when all the burners are lighted, a light cambric handkerchief can be laid, without exhibiting the slightest sign of scorching. The advantages are manifest: great security from fire; thorough and complete removal of the products of combustion, a most important matter in connection with the ventilation of theatres; and all this without any increase of cost, as the patent float is in every way as thoroughly efficient for lighting purposes as those heretofore in use.

We may here notice an ingenious little contrivance for bed-room use, to show the "time of night." A gas-burner alight all night in a bed-room is apt to produce a certain closeness of atmosphere, which, if not carried to the point of unhealthiness, is nevertheless very often uncomfortable; at the same time a certain amount of light in a bed-room is always desirable, with the object, if no other, of being able to see "what time it is."

The ordinary gas-bracket is modified in construction by a bent arm attached to an angle in the centre of about 90°, and at the angle is placed a jet, so small as to provide only a little bead of flame. At the end of the bent arm is the ordinary burner and globe; at the end of the straight arm is adjusted a magnifying-glass, so arranged that when the sleeper's watch is hung against the wall, on a hook provided at a proper point for the purpose, by a single glance he can see the time by the light given by the tiny gas jet provided for the purpose. The necessary fittings cost only a few shillings; but for invalids, etc., it provides a certain comfort at a small expense.

GENERATION OF STEAM-POWER BY GAS.

Although not strictly a domestic object, yet in large warehouses and hotels it has been introduced for what may be called household purposes, lifts, etc.

The method adopted is to introduce a small steam-engine, generally of about two-horse power, with a boiler of ordinary construction in all respects but one, and that is, that instead of being heated by a coal-fire, the necessary heat is generated by a series of groups of gas-burners fixed below, which may be described as small compact sun-burners, four or five inches in diameter, consuming the gas mixed with a certain per-centage of atmospheric air, on the same principle as we have previously described in our paper on "Cooking by Gas." The cost of the gas required to work a small steam-engine, as above, has been ascertained by experiment to be about sixpence per hour.

The detail of the machinery for the engine and lift is beyond the scope of our present subject, but the necessary information can be readily obtained from those conversant with similar matters.

The small engine and boiler together will only occupy about fifteen feet superficial of room, and may be taken as costing about £200; and we may mention, as a practical instance of the successful application of the principle, Messrs. Leaf's well-known warehouses in Old Change, where a lift is worked, which delivers all the goods to the several floors of a lofty warehouse, doing work which, under ordinary circumstances and by manual labour alone, would require from twenty to thirty men. Neither stoke-hole or other appliances necessary for ordinary steam-power are required; and there is this important commercial advantage, that the fire-offices charge no extra rate for this peculiar description of machine.

We conclude our series of papers on gas by a notice of an engine recently introduced, which avails itself of gas as a motive-power, but in a somewhat novel manner: we allude to

HUGON'S GAS-ENGINE.

In all our previous descriptions of various appliances of gas the gas is burnt in the ordinary way, through burners of various forms and combinations, care being always taken where atmospheric air is burnt in conjunction with it that the mixture shall be kept *below* that point at which it becomes explosive, as it is well known that a certain per-centage of admixture of gas with atmospheric air is excessively dangerous; and when we read of explosion of gas it is never the pure gas that explodes, as of itself it does not possess that property, but only acquires it when in the combination above mentioned. In the Hugon gas-engine, however, this particular explosive mixture is utilised as the moving element in the machine. It resembles in its construction a small horizontal steam-engine. It is usually constructed of one or two horse-power; and the motion backwards and forwards of the piston is obtained by filling either end of the cylinder alternately with what may be termed a charge of gas and atmospheric air, mixed in the proper proportions, which is then, by the self-acting motion of the machine, brought into contact with a lighted gas-jet at either end of the cylinder alternately, when combustion, or more properly explosion, at once ensues. No boiler is of course required; the gas has to be laid on, and that is all. The products of combustion are almost *nil*, as the remnant of each explosion is only a small quantity of moisture. The motion is regulated by a fly-wheel, as in the case of an ordinary steam-engine; and upon the shaft of this wheel pulleys can be fixed, and by means of bands or otherwise all the operations of light machine-work carried on—pumping, grinding, hoisting, and all cognate processes, requiring only the adaptation of the requisite machinery.

An engine of one horse-power costs £80, and a three horse-power £130. Scarcely any setting is required. It is almost as easily fixed as a billiard-table; and when not actually at work there is no expense whatever. The consumption of gas for a small-sized engine may be taken at sixpence per hour.

With the sundry matters included in this paper we conclude the subject of gas as a branch of domestic sanitary engineering. We have briefly described the process of manufacture, the method of measurement, and in the series of eight papers upon the subject given the detail, as far as our space would permit, of the different mechanical appliances required for its economical use. In some following papers on warming, ventilation, etc., we may have occasion casually to allude to the subject again, but for the present we dismiss the subject of gas as a branch of domestic sanitary engineering.

TECHNICAL DRAWING.—XLII.

DRAWING FOR STONEMASONS.

FREE-HAND DRAWING FOR STONEMASONS.

FIG. 385.—This moulding is called a *cavetto*, the name of which is derived from the Latin word *cavus*, "a hollow." It is a concave moulding, the curvature of whose section does not exceed the quarter of a circle. Its projection may be equal to its height, and should never be less than two-thirds of it. The cavetto, which is the reverse of the ovolo, is sometimes used in the bed and crowning mouldings of cornices.

The method of drawing the cavetto will not require any explanation.

Fig. 386.—The *scotia* is a recessed moulding of an elliptical section, when properly constructed. It is, however, for general purposes formed by the junction of two circular arcs of different radii. This moulding has an effect just the opposite to that of the ovolo or torus, and is sometimes composed, like the latter, of a semicircle only.

To draw the scotia, divide the height of the moulding into three equal parts. From any point, as a, on the line drawn at two-thirds from the bottom, draw the quadrant $a\ b$; from a on the same line set off $a\ c$; from c, with radius $c\ b$, describe the quadrant $b\ d$, which will complete the moulding.

Fig. 387 is a section of the frequently-used moulding called the *cyma recta*. The exact form of this moulding is, to a certain extent, a matter of taste, since the curve may be drawn more or less full, the variation being caused by the radius with which the arcs are struck. The curve most generally used is given here, and the following is the method of describing it:—

Let a and b be the points to be united by the moulding. Draw the line $a\ b$, and bisect it in c; from c and a, with radius $a\ c$, describe arcs cutting each other in d; from c and b describe arcs cutting each other in e; and from d and e, with the same radius, describe arcs meeting in c, which will give the form of the moulding. If it be required that the lower portion of the curve should be more full than the upper, divide the line connecting the two extremities of the section into three equal parts, construct an equilateral triangle on the upper third, and another on the *two* lower portions, then the apices (plural of *apex*, "the upper point") of the triangles will be the centres from which the arcs are to be struck. This and several other methods of describing various mouldings are described and illustrated in Vol. I., page 199.

Fig. 388 is the *cyma reversa*. In this moulding the curve bulges outward at its *upper* part, and it is hence the reverse of the cyma recta. As in the former figure, the exact form is regulated by the taste of the designer. In this and all the curves composed of combined arcs, the greatest care is necessary, so that the one may glide smoothly into the other without showing any break or thickening in the joining, which materially injures the effect. This has already been referred to, and it will be at once seen how the taste, when cultivated by the study of ornamental drawing, will aid in the appreciation of these forms, which add so much to the beauty and gracefulness of the building.

METHOD OF DESCRIBING A RAKING MOULDING.

Raking is a term applied to such members of a building as slope or lie inclined to the horizon. Raking mouldings frequently occur in masonry, and the following example will explain the method of forming them to mitre in a proper manner:—

Fig. 389.—This is the design of a cornice, having part of the moulding level and part inclined, as occurs in the pediment of a building. In this drawing $a\ e$ is the moulding at the angle of the break or projection of the pediment. With this moulding given, we have to find the right section of the ogee in the pediment.

Let $a\ f$ and $e\ e'$ be the two parallel lines which terminate the breadth of the raking, or inclined moulding; and let $a\ k$ and $e\ l$ be the parallel lines terminating the breadth of the moulding which is level.

At a convenient place draw $p\ t$ parallel to the edge $a\ k$ of the horizontal portion of the moulding. Between a and e place any number of points, as b, c, d, and draw $b\ g$, $c\ h$, and $d\ i$ parallel to $a\ f$ and $e\ e'$.

At a, b, c, d, e draw perpendiculars to $e\ l$, cutting the line $p\ t$ in q, r, s.

Now, at any convenient distance, draw a line parallel to $a\ f$. and transfer to it the distances t, s, r, q, p—viz., t', s', r', q', p'.

From each of these points draw lines at right angles to $a\ f$ and $e\ e'$, cutting $a\ f$, $b\ g$, $c\ h$, $d\ i$, and $e\ e'$ in A, B, C, D, E. The curve traced through A, B, C, D, and E will be the right section of the raking moulding.

To find the section through the mitre of the two inclined sides where they meet at the top of the pediment, draw $t''\ p''$ perpendicular to $t''\ e'$, and equal to $t\ p$. Transfer the distances from these to the space between t'' and p'', and draw perpendiculars from s'', r'', q'', p''.

From f, g, h, i draw lines at right angles to $f\ e'$, and through the points where these intersect the perpendiculars—viz., a', b', c', d', and e'—draw the curve which will be the common section of the mouldings at their junction at the apex of the pediment.

The method of constructing simple scales having been given in lessons in "Building Construction," it is not necessary here to repeat the instructions; the subjects in this figure are drawn to the scale of half an inch to the foot. It is advisable to draw the scale on each sheet, as by measuring from this, instead of from the rule, the trouble of calculating how many inches so and so many of the fractions make is avoided, and generally greater accuracy is obtained.

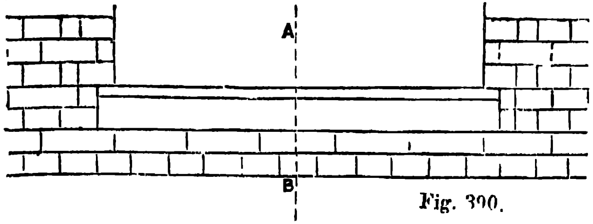

Fig. 390.

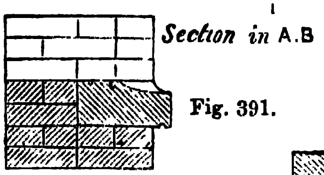

Fig. 391.

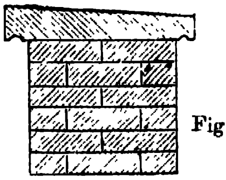

Fig. 392.

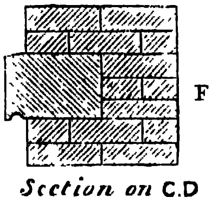

Fig. 394.

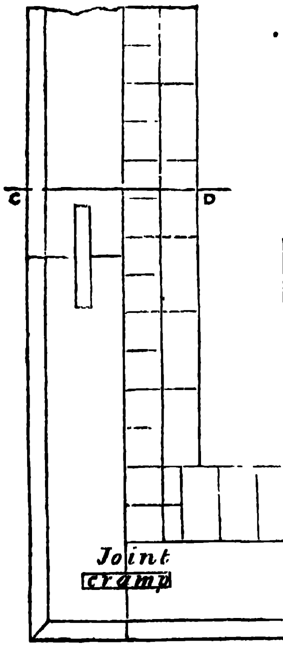

Fig. 393.

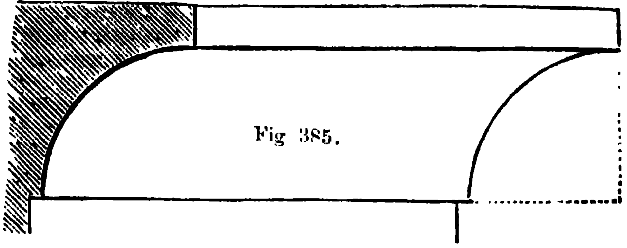

Fig. 385.

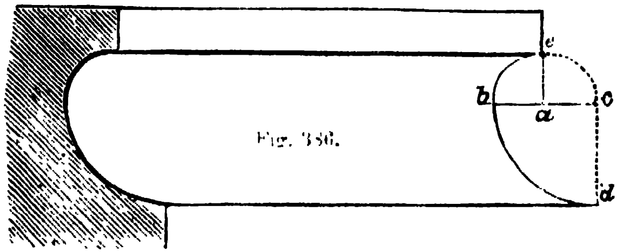

Fig. 386.

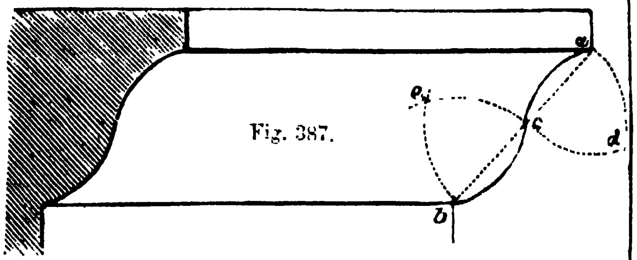

Fig. 387.

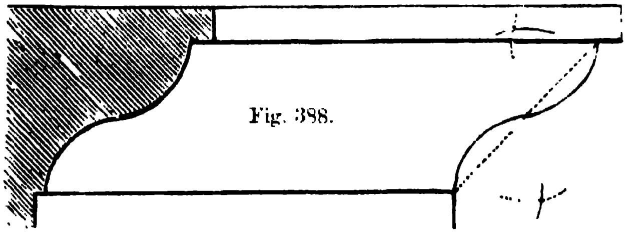

Fig. 388.

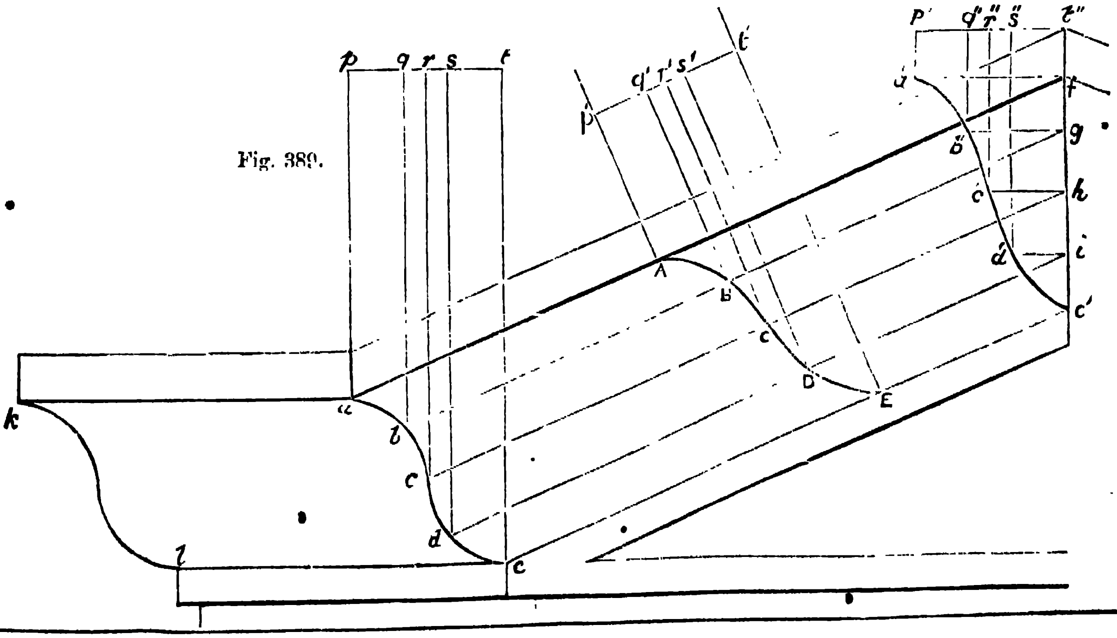

Fig. 389.

As a portion of the present study consists of brickwork, the following brief extract from lessons in "Building Construction" is given, in order to remind the student of drawing for masons of some particulars which, thinking they did not specially concern him, he may have merely glanced over whilst reading the lessons treating of the subject generally:—

"Bricks may be considered as artificial stones, and seem to have been used from the very earliest period in the history of man. Their average size in this country is a trifle less than 9 inches long, 4½ inches wide, and 2½ inches thick. Their uniformity in size enables builders to describe the thickness of walls by the number of bricks extending across them; thus a slight brick partition wall, being formed of bricks lying on their broad side, with their length in the direction of that of the wall, is called a 'half-brick thick,' its depth from one side to the other being 4½ inches. A wall in which the length of a brick extends through the thickness is called a 'one-brick thick.' A wall 14 inches through is called a 'brick-and-a-half thick,' though, to speak more accurately, it would be 13½ inches—that is, 9 for the whole brick, and 4½ for the half. An 18-inch wall is said to be a 'two-brick thick,' and so on."

Fig. 390 is the elevation of the lower part of a window, showing the window-sill.

It will be seen that the wall is built in old English bond, and that the stone sill is equal in height to two courses of brickwork. The opening of the window is four feet wide; the brickwork covering the ends of the sill to the width of two inches on each side. It will also be observed that in order to avoid the joint in the courses of bricks at the sides coming immediately over each other (which would occur if two bricks placed as headers were placed upon one stretcher), cut bricks, called "closers," are used. This has been explained in lessons in "Building Construction."

Fig. 391 is the section in A B, and shows the manner in which the sill is sloped off, or "weathered," and throated underneath. Both of these terms will be explained in connection with the next figure.

Fig. 392 is a section of a *coping*. This term is used for the series of stones used as the capping or covering of a parapet or wall. The name is generally applied to a plain, slightly projecting course, and *cornice* to a larger moulded coping.

Copings are worked with a plain horizontal bed, two vertical faces, and an inclined or "weathered" upper surface, either forming an obtuse angle with the inner and narrower face, and an acute angle with the outer wider face, or slanting off from the middle towards each side, which latter is technically termed a "saddle-back coping." In both cases they are made to project over the wall or parapet on both sides, and in the projected part of the bed, under the edge or edges towards which the inclination is given, a channel or groove, called a "throat," is cut, to intercept the water in its inclination to run inwards towards the wall. To protect the separate stones of a coping course from the danger of being displaced by high winds or other accidental causes, and to form a chain through its whole length, the stones are linked together by cramps of copper or iron let into them and run with lead. These metals, however (says Mr. Hoskings), especially the iron, for the most part act very injuriously, from their exceeding susceptibility of atmospheric changes, and their greater or less tendency to oxidation; indeed, the stone invariably suffers more than the work benefits from the metal cramps. Tenons, dowels, joggles, or dovetails of stone, or of hard wood, or cast iron, applied so as to be protected from the weather, would be far better, and would answer every desired purpose sufficiently.

A *string course*, shown in plan in Fig. 393, and in section in Fig. 394, is meant to protect a set-off in a wall, by projecting over its lower face in the manner of a coping.

The beds are worked parallel, and the outer face vertical, or at right angles to them, but so much of the outer surface as protrudes from the wall is "weathered," or sloped off to carry the water away; and, for the reason already stated with regard to copings, the lower bed just within the outer face is throated. A string course cramped or dovetailed in the bed forms an excellent chain around a brick wall, but the part of it in the wall should be of the exact thickness of one, two, or more courses of the brickwork. The method of drawing these examples is so very simple, that it is not thought necessary to give any instructions on that head.

SEATS OF INDUSTRY.—XVII.

COVENTRY.

BY WILLIAM WATT WEBSTER.

A FEW of the leading facts relating to the history of silk culture and silk manufacture may not inappropriately preface an account of the city of Coventry, so long a centre of the silk manufactures of England. In the Old Testament there are three references to silk as an article of clothing: one in Proverbs, which is believed to have been written 1,000 years B.C.; and two in Ezekiel, which dates from about the beginning of the sixth century before Christ. But silk manufacture can be traced back to a far more remote antiquity than the Proverbs of the merchant king of Israel. According to the traditions of the Chinese, the rearing of the silkworm and the weaving of silk into robes formed part of the occupation of the ladies of the royal household of China 2,700 years before the Christian era, and the discovery and utilisation of the fibre is ascribed to the consort of one of the celestial emperors. The silkworm, indeed, would appear to be indigenous to China; or, to speak more strictly, to Serica or Serinca, that part of India lying beyond the Ganges. "Seres is the name given by the Greeks and Romans to the inhabitants of these remote regions," says Dr. Lardner, and "it is now so generally admitted that the Seres of the ancients are the Chinese of the moderns, that it is unnecessary to enter into any discussion in proof of this belief. *Se* is the name for silk in the Chinese language; this, by a faulty pronunciation, not uncommon in their frontier provinces, acquired the final *r*, thus changing the word into *ser*, the very name adopted by the Greeks. We can, therefore, hardly doubt," he adds, "that these obtained the name, as well as the material itself, first from China." The Latin name for silk was *sericum*, of which *silicum* is supposed to be a corruption. For a remarkably long period the Chinese seem to have retained a complete monopoly of the cultivation of silk, and even of its manufacture. In the time of Aristotle the inhabitants of the island of Kos were in the habit of unweaving the heavy silk fabrics of China, purchased from Persian and Phœnician merchants, and of re-spinning and re-weaving them into lighter cloths. This process is said to have been invented by Pamphila, and to have been the origin of silk gauze. Alexander the Great brought woven silks to Greece from Persia, and in the works of Aristotle, his tutor and friend, is to be found an accurate description of the silkworm. But it was not till about the year 550 A.D., in the reign of Justinian I., that the cultivation of silk was introduced into Europe by two Persian monks who had visited India as missionaries. "There," says Robertson, the author of "Disquisitions on the Commerce of India," "amidst their pious occupations, these monks viewed with a curious eye the common dress of the Chinese, the manufacture of silk, and the myriads of silkworms, whose education, either on trees or in houses, had once been considered the labour of queens. They soon discovered that it was impracticable to transplant the short-lived insect, but that in the eggs a numerous progeny might be preserved and multiplied in a distant climate." Carrying off a quantity of the eggs of the bombyx concealed in a hollow cane, they returned to Persia, and from thence sent a communication to the Emperor Justinian, to the effect "that the Romans need not any longer be obliged to purchase raw silk of the Persians, nor of any others; for having lived long in a country called Serinda, they now assured him that, although the origin of raw silk was till now a secret from the West, it proceeded from certain worms taught by Nature to spin it out of their own bowels; and that though it was impracticable to bring those worms so far alive, yet it would be easy to procure their bags, which would produce the worms." Justinian took the manufacture into his own hands, and appointed the monks to superintend the rearing of the worms. Shortly after this period silk culture was established in Greece, and especially in Peloponnesus, and a great trade was carried on in silk goods by the merchants of Venice, who formed the channel through which the silk produce of Greece was transferred to the west of Europe. In 790 Charlemagne sent two silken vests to Offa, King of Mercia, as a present. Up to the middle of the twelfth century the far East, Constantinople, and Greece were the sole sources from which silk was supplied. It was in 1146 that Roger II., King of Sicily, having conquered Greece, brought to Palermo a band of prisoners who had in their own country been employed in rearing and weaving silk, and by their means laid the foundation of this industry in Italy, from whence it subsequently spread to France and Spain.

At the marriage of Margaret, daughter of Henry III. of England, with Alexander III. of Scotland, in 1251, 1,000 English knights clad in silken raiment were present; but their robes must have been spun and woven, if not made, abroad, as several centuries had to elapse before any silk manufacture was established in Britain. About the beginning of the fifteenth century a company of silk-women was established in London, and in 1455 an Act of Parliament was passed which, "upon the heavy complaint of the women of the mystery and trade of silk and thread workers in London, that divers Lombards and other foreigners enriched themselves by ruining the said mys- ," directed "that no wrought silk should be brought into land by way of merchandise for five years to come." ing the reign of Mary, every one below the dignity of a istrate was prohibited, under the penalty of three months' risonment and a fine of ten pounds, from wearing "silk in or upon his or her hat, bonnet, or girdle, scabbard, hose, shoes, or spur-leather." Numerous sumptuary and protective laws were subsequently passed which materially affected the progress of the silk trade and manufactures in England. It was in the reign of James I. that the weaving of broad silks was first commenced in this country, and by 1629 this branch of industry had increased to such proportions that the silk throwsters of London were incorporated. But the silk manufactures of England never attained any great importance until after the revocation of the Edict of Nantes. In the year 1685 a large number of French Protestant refugees, including many skilled silk-weavers, settled in Spitalfields, London. These foreign artisans introduced the manufacture of alamodes, lustrings, brocades, satins, velvets, and other fabrics that previously had to be imported. The next important step in the history of the English silk manufactures was the erection of a great silk-throwing machine on the Derwent, in 1719, by Sir Thomas Lombe, of Derby, and his brother John, constructed from drawings which the latter had surreptitiously obtained at Leghorn, then the principal centre of the Italian silk trade. In 1715 John Lombe went to Leghorn to observe the silk machinery in use there, and, if possible, to bring the secret home with him to England. Finding that he could not obtain any useful knowledge by watching the machinery during the hurried visits strangers were allowed to make to the mills, Lombe, who was a very young man, disguised himself as a youth out of employment, and with the assistance of the priest who acted as confessor to the proprietor of the works, and whom Lombe is believed to have bribed heavily, he got an engagement to attend a spinning-engine called a "filatoe." Concealing his dark-lantern, tinder-box, and mathematical instruments in a hole below the stair where he slept, Lombe night after night made drawings of the different parts of the machinery, which his priestly accomplice handed over to the Italian agents of the Messrs. Lombe, for transmission to England in bales of silk. When the whole of the machinery was carefully drawn, Lombe got on board a ship, and although his flight aroused instant suspicion, and an Italian brig was despatched to intercept him, he arrived safely in England. "There is a tragical story told of his death," says Lombe's biographer, "which is likely enough to be true. It is said that the Italians, when they heard of the whole affair, sent over a female to England to poison him. Lombe had brought over with him two Italians, who were accustomed to the manufacture he had risked so much for. The woman succeeded, through the means of one them, in administering a deadly poison."

Sir Thomas Lombe received a patent for his silk machine, and although, on the expiration of the patent, Parliament refused to renew it, he obtained a sum of £14,000 "as a consideration for the eminent services he had done in discovering, in introducing, and bringing to full perfection, at his own expense, a work so useful and beneficial to the kingdom." But however profitable this undertaking may have proved to Sir Thomas Lombe, the best authorities are agreed that the establishment of throwing machines was indirectly one of the most formidable obstacles to the development of the silk manufactures of this country, as the existence of throwing-mills was successfully urged for nearly a century as a sufficient reason for levying oppressive duties on thrown or organzine silk. And yet it can hardly be doubted that the silk manufactures of England have been largely indebted to the enterprise and the sharp practice of the Lombes.

It is impossible to fix the precise date when spinning and weaving were first introduced into Coventry, but the local annals of the city prove that it was celebrated for the manufacture of cloth caps and bonnets, and a kind of thread known as "Coventry true blue," early in the sixteenth century. From 1581 till 1694, when the Turkey trade was destroyed, the manufacture of woollen broadcloths of various descriptions was the staple trade of the town. It is not improbable that the ribbon trade was carried on in Coventry at the latter date, or, at least, shortly after, as in 1705 we find that William Bird, silkman, was mayor of the city. It is supposed that several of the silk weavers who arrived in England in 1685 settled down in Coventry, and laid the foundation of its ribbon manufactures. At first this industry was carried on upon a small scale, and it was only by degrees that Coventry rose to be the chief emporium for ribbons in England.

The silk-trade of Coventry has passed through many vicissitudes, it having been affected, not only by the ordinary calamities that depress other trades, but also by changes in the fashions, and other causes peculiar to itself. About a century ago, the manufacture of watches was introduced into Coventry, and so greatly has this industry prospered, especially during the past half-century, that a greater number of watches are now annually made in this city than in London, while the quality of the article produced is not surpassed by the watch manufacturers of London.

Coventry is situated on the Sherborne, an affluent of the Avon, 85 miles N.W. of London, and 18½ miles S.S.E. of Birmingham. The name would seem to denote that the city took its origin from a convent, but of this no authentic proof can be given. It is believed, however, that Leofric, Earl of Mercia, and his wife, the celebrated Lady Godiva, founded a Benedictine monastery there about the year 1044. The story of Lady Godiva, which is first mentioned by Matthew of Westminster, in 1307, or some two hundred and fifty years after the time when that lady lived, may be purely legendary, but it has contributed to spread the fame of Coventry abroad through the world, at least as much as its ribbons and watches. Sculptors, painters, and poets have so frequently illustrated this fictitious or real incident in the history of Coventry, that it is unnecessary to repeat the details of the story here. Every third year the memory of Godiva's devotion to the people is still celebrated at Coventry by a procession, and up till the passing of the Municipal Reform Act the ceremonial was graced with the presence of the mayor and corporation in their official robes. It was not a feat suitable for realistic representation, and we are not sorry to hear that the procession is losing favour with the inhabitants. In this connection it may be mentioned that Coventry was celebrated in the fifteenth century for the religious mysteries or plays performed there by the Grey Friars in the presence of the kings, who then resided in the city, and also for the gorgeous pageants and processions that its inhabitants indulged in. Several parliaments were convened at Coventry by the ancient kings of England; one held in 1404 being known as the *parliamentum indoctum*, from the fact that lawyers were prohibited from taking part in its proceedings; and another which sat in 1459 was called *parliamentum diabolicum*, on account of the number of acts of attainder passed by it. The city was incorporated by Edward III., and the first mayor was chosen in the year 1345. Coventry has sent two members to the House of Commons since 1453. In Roman Catholic times it possessed a large and handsome cathedral, which was destroyed in the time of Henry VIII. During the civil war of the seventeenth century Coventry was conspicuous for the support it gave to the Republican cause.

The more modern quarters of the town of Coventry are well built and regular, but it still preserves several narrow and crooked streets, with houses in the style of the fifteenth and sixteenth centuries, composed of heavy wooden beams filled in between with bricks and plaster, and in some cases having peaked upper storeys, projecting far over the under-floor, and darkening the thoroughfare. Great improvements have been effected in the city within the past few years. Among the most remarkable of the public buildings are St. Michael's Church, a masterpiece in the lighter Gothic style, with numerous windows filled with ancient stained glass, and having a fine spire 363 feet high; Trinity Church, with a spire 237 feet high; and Christ's Church, a modern building, attached to the elegant spire of the Grey Friars Monastery. These are the "three tall spires" of Coventry. St. Mary's Hall, erected in 1450, also deserves notice, as it is one of the finest specimens of the ornamental work of the fifteenth century in England. The roof of this hall is finely and grotesquely carved, the walls are hung with ancient tapestry, and it is lighted by a great painted window. The charitable institutions of Coventry are numerous and well endowed. Of these we may note Sir Thomas White's charity, founded in the reign of Henry VIII., which possesses an annual revenue of between £2,000 and £3,000; the Bablake Men's Hospital, with estimated income of £1,500; and the Bablake Boys' Hospital, with an income of about £940. It has also a Free Grammar School and several charity schools. In ancient times Coventry was surrounded by walls three miles in circumference, and three of the gates and a portion of the walls still remain standing. Around the city there are 2,300 acres of common land, on which each of the freemen has a right to pasture three cows.

MINING AND QUARRYING.—XI.

BY GEORGE GLADSTONE, F.C.S.

IRON.

SIEMENS' REGENERATIVE GAS-FURNACE—BESSEMER PROCESS OF PUDDLING—PIG-BOILING—THE FORGE—MACHINES FOR SQUEEZING AND HAMMERING THE PUDDLED BALL.

It was seen in the last article that puddling, as ordinarily conducted, is both an expensive and laborious process. We have now to speak of some very different arrangements which are coming into more general use, by which some of the objections to the old process are more or less obviated.

First, we must consider the adaptation of Messrs. Siemens' regenerative gas-furnace to this operation, by which some substantial advantages are gained. The first of these consists in economy of heat. In the ordinary puddling-furnace there is a great waste of this, as is sufficiently evidenced by the flames issuing from the chimneys, which at night may be seen illuminating all the country round; but in Messrs. Siemens', the heated gases pass from the hearth to the regenerators, so as to do double duty, the heat being so completely utilised that the flue always remains cool.

The arrangement adopted is shown in Figs. 11 and 12. The gas-producer and the regenerator are situated below, A and B being the channels for the passage of the heated gas to and from the hearth C, which is provided with water-bridges, D D, the overflow from which passes into the tank E. A current of air passes through the apertures F F (Fig. 11), over the water in the tanks; and this, coupled with the evaporation of the water, keeps the iron plate forming the bottom of the hearth cool. G, G are ovens for heating the iron for the next charge, preparatory to its being put in the hearth, by which a considerable saving of time and heat is effected, less than one hour being sufficient for the whole operation. Secondly, the reduction in time probably accounts partly for the fact that there is no loss of metal in puddling by this process; while the facility with which the gas-flame can be made either reducing or oxidising at pleasure, reduces the chance of loss to a minimum. One of these furnaces, in eighty heats, has actually returned more puddled metal than the pig-iron supplied, the actual figures being 38,808 pounds, against 38,668 pounds. Now, as the weight of the impurities removed will be something considerable, even allowing for no loss of iron at all, it is evident that something more than this must be supplied by way of compensation from the oxide used in fettling. By the ordinary process no account is taken of any such gain, as the net result always shows a considerable loss.

A third advantage which has been incidentally alluded to is the reduction of time, or, to put it in another form, a reduction of labour—eighteen heats have been turned out from three furnaces in twenty-four hours, against twelve, which is the full work of the ordinary furnace. Lastly, the quality of the produce is superior, as there is no risk of any impurities being carried by the draught from the fuel to the hearth.

An altogether different process must now claim our attention. It is commonly known by the name of the inventor, Mr. Bessemer. The principle which lies at the foundation of it is that of raising the iron to a very violent state of ebullition, by forcing air through the molten metal, and thus bringing every particle of it in contact with the oxygen. It was attended at first with numerous practical difficulties, but these have been overcome in time, and the process is now very largely used. In the course of a few minutes the puddled iron is obtained from the crude pig, without the intervention of the puddler, the whole being done by machinery, which only requires the attention of one man.

The important parts of the apparatus required are the converter, a hydraulic machine for moving it, and a blowing engine. The form of the converter will be best understood by a reference to Figs. 13 and 14, which represent a vertical section and an elevation, showing the trunnions upon which it swings, and the arrangement for introducing the blast. The converter is an ellipsoid vessel of iron of about 13 feet in height, consisting of two separate portions firmly bolted together. The lining, C, has to be renewed from time to time, generally after seventy-five or eighty charges, and for this purpose the bolts have to be unscrewed. The lining consists of fire-clay and pounded sandstone, well mixed, and tightly pressed down upon the iron frame; it must be carefully dried, and any cracks that may appear made good before using. B, B are twyers (generally seven in number), which are made of fire-brick, pierced with small holes; these have to be renewed about every third time. The blast is brought to them through the pipe A A, passing through one of the trunnions, which is made hollow for the purpose; by this arrangement the blast can be continued whatever may be the position of the converter, the essential importance of which will be seen presently. The hydraulic engine for moving the converter is connected with the opposite trunnion at D, so that the man can work it from a distance.

The charge of pig-iron (about 3 tons) is introduced into the converter in a molten state; it might be run direct from the blast-furnace, but practically it is more convenient to remelt the iron for the purpose. In receiving the charge the converter is thrown into a horizontal position, with the mouth E turned upwards, and while the vessel remains thus the iron will rest upon its side without touching the twyers. The blast is then turned on, and the converter raised again to the vertical position, when the iron will cover the twyers to about the depth shown in the drawing; but had the blast not been supplied first, the iron would have got into the twyer-holes and choked them up. The iron immediately begins to boil violently, filling the whole converter, and throwing out from the mouth a shower of burning scoriæ and iron. In about a quarter of an hour or twenty minutes the whole of the carbon has been burnt, and the silicon and earthy matters separated; the iron now, almost as limpid as water with the intensity of the heat evolved, being ready to be poured out into the moulds. For this purpose the converter has again to be tilted over, the blast being kept on in full action until the twyers are above the surface of the metal.

The loss in weight during the process (including the preparatory melting) amounts to about 22½ per cent., so that in this respect it is not economical; a good deal of iron is, however, thrown out of the converter in the shape of sparks, which is of course recovered. The separation of the silicon seems to be almost perfect, and the carbon also is much more thoroughly removed than is practicable by the ordinary process; unfortunately, however, the sulphur and phosphorus are not affected to any appreciable extent, so that the Bessemer iron retains the most deleterious of all the impurities. This one circumstance has rendered the process inapplicable to the common pig-irons, and has practically limited it to those made from the hæmatites and other very fine ores. It is therefore principally valuable in the manufacture of steel, and will have to be referred to again when treating of that article.

Some iron-masters substitute "pig-boiling" for the refining and ordinary puddling; one operation thus suffices instead of two, but economically there does not seem to be much difference in the result. The furnace is made upon the type of that for puddling, except that the hearth is deeper; some cinder is added to the charge of pig-iron, and a higher temperature is employed. There is a more violent action in the giving off of the carbonic acid, which has given rise to the name adopted, but otherwise the process is very similar.

In some works the waste heat from the puddling-furnace is utilised in the raising of steam, and in others the waste gases of the blast-furnace have been used as a substitute for fuel in puddling. Such arrangements as these for effecting economies in the supply of heating power deserve to be more carefully considered when planning the erection of works.

We must now consider the treatment to which the puddled ball is subjected, in order to convert it into bar or sheet iron.

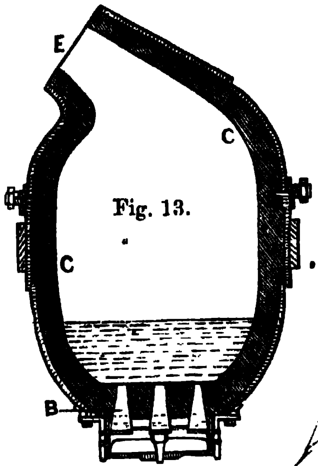
Fig. 13.

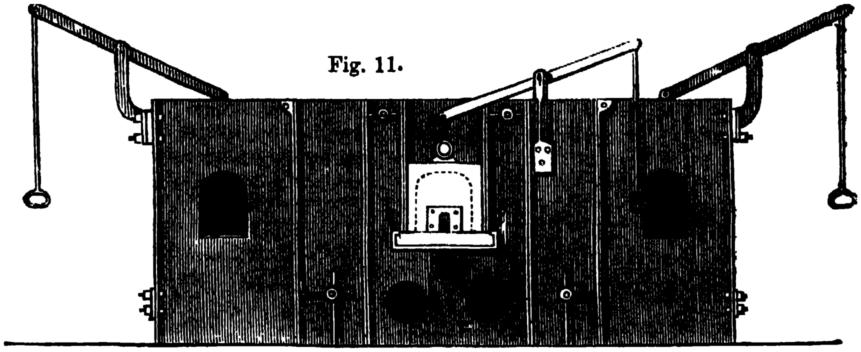
Fig. 11.

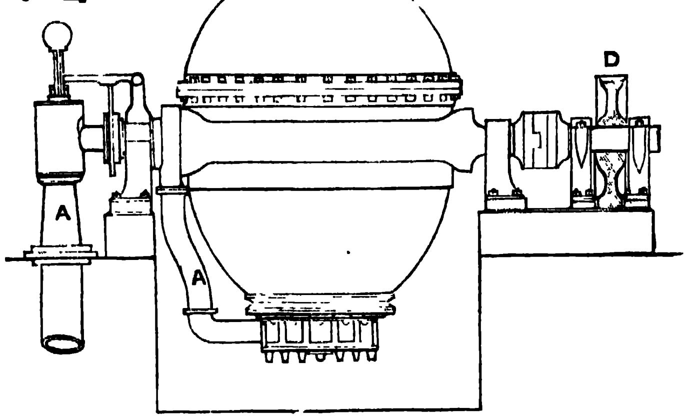
Fig. 14.

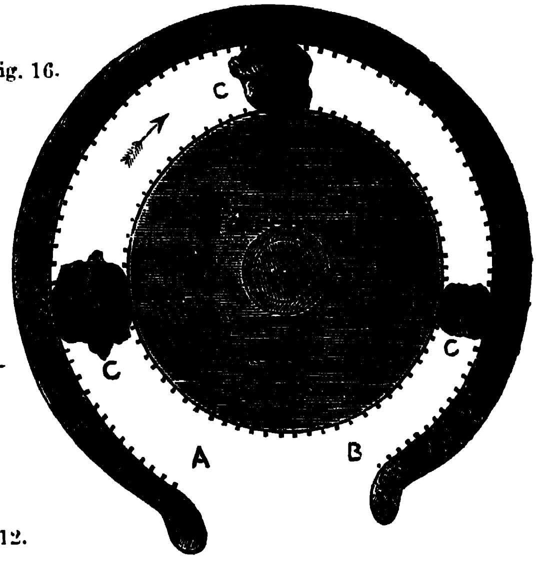
Fig. 16.

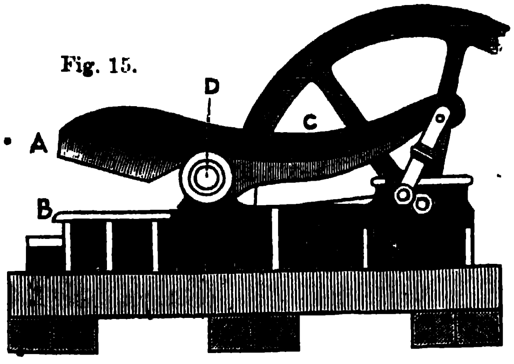
Fig. 15.

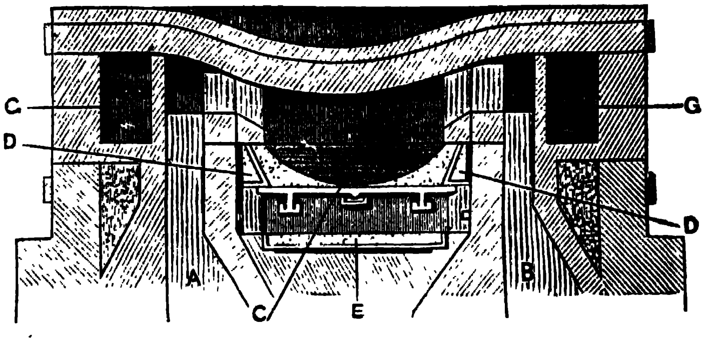
Fig. 12.

The part of the establishment to which we now pass is called the forge. The ball, as may readily be imagined from the description of its preparation given in the last article, though consisting of malleable iron, is far from being a solid mass, and contains more or less of the cinder mixed with it. This has literally to be beaten and crushed out.

The forge contains a variety of hammers, squeezers, and rollers, of great weight and power. Opinion is divided as to the respective merits of hammering and squeezing, and both plans continue in such general use that they cannot be passed over: in either case the process is termed "shingling," and the workmen "shinglers."

We will consider first the squeezers, of which there are a great variety of forms, but mainly referable to two distinct types. The simpler will be readily understood by a reference to Fig. 15. The puddle-ball, while yet quite hot, is placed upon the iron plate B, and at every revolution of the fly-wheel, which is driven by steam, the massive upper jaw A comes down with great weight upon the ball, forcing the particles of iron into close contact, and at the same time expelling any cinder that may be mixed up with it. The jaws are very commonly grooved or toothed, rendering them eminently suggestive of those of a crocodile, so that this form of squeezer very generally bears that name. All that the shingler has to do is to move the ball in the intervals of pressure, so that all parts of it may be thoroughly acted upon. The machine can be driven at great speed, so as to give the jaw from eighty to ninety actions per minute. As much as 100 tons of iron will pass under one of these squeezers per week. By a slight modification of the arrangement, a double-acting machine can be made; the beam C being armed with another jaw on the opposite side of the pivot D, so that two balls may be squeezed at the same time.

The other form of squeezer is made upon the principle of compelling the ball to pass between rollers, which approach each other more closely as they complete their circuit. The horizontal rotary squeezer consists, for instance, of an iron drum, open on one side, with an iron cylinder within, which turns upon a centre slightly differing from that of the drum itself. The space between the cylinder and the drum will therefore be less in one part of the circuit than the other. The puddled ball C is inserted at A (Fig. 16), and the revolution of the cylinder, which is armed with small teeth, carries it forward in the direction of the arrow through the narrower portion, and ejects it at B in a highly compressed state.

Other shingling machines are so constructed that the mass of iron falls down between three or more revolving cylinders, so arranged and of such form that the space through which the ball passes in its descent is constantly narrowing; the action upon the metal is similar to that of the rotary engine, the difference consisting in the mechanical arrangement.

The use of hammers is of older date than the first adoption of squeezers; but we have deviated from the chronological order because of some modern inventions, which enable pieces of iron of a size never before attempted to be forged by means of the hammer.

The older forms are called tilt-hammers and helves. The former consists of a long beam working on a pivot, to the longer arm of which is attached a head, below which lies the anvil. The hammer is driven by a wheel furnished with cams, which, as they revolve, press down the shorter arm and raise the hammer-head. These are generally of comparatively light construction, and are worked at a considerable speed.

The helve is a much more ponderous instrument; the beam is made of cast-iron, to which is fitted a wrought-iron hammer-face, the two together weighing ordinarily from 3 to 5 tons, but up to 10 tons in some instances. The beam works upon a pivot at the extreme end, and is lifted by a wheel, the cams of which lay hold of a projecting portion immediately adjoining the hammer-head. These have a less length of stroke, and work more slowly, rarely exceeding one blow every second, but their great weight renders them very effective instruments. The hammers are indeed considered to turn out a better article than the squeezers, but they are worked at greater expense, the wear and tear of the head and the anvil being very great. These, indeed, seldom last more than a week.

The most powerful instrument of all, however, is the steam-hammer, with which Nasmyth's name is naturally associated, though other inventors have patented modifications of the same principle. The hammer-head is attached to the end of the piston-rod, and is raised and lowered by the direct action of the steam in the cylinder. So well-known a machine does not require detailed description here, beyond pointing out its special advantages in connection with the forging of iron. When a ball of metal is put under one of the other hammers, it is subjected not merely to a heavy, but at the same time sharp blow, and no means exist of regulating the force of it except at a loss of power; whereas in the steam-hammer the force can be applied as gradually as the workman pleases. An imperfectly puddled ball will thus fly to pieces under the blow of a helve, which will not suffer under the more gentle, though not less efficient, action of the steam-hammer. They are now almost universally adopted in the very largest forgings.

NOTABLE INVENTIONS AND INVENTORS.

XIX.—GLASS-MAKING.

BY JOHN TIMBS.

In the whole range of human invention it would be difficult to point to a more ingenious or interesting result than the manufacture of glass. Although perfectly transparent itself, not one of the materials of which glass is made partakes of that quality; a combination which may, at the period of its invention, have been as astounding as the identity of carbon and the diamond, established by the chemical philosopher of our time.

Glass was long considered to be a strictly chemical combination of its ingredients; such, however, is not the case, the alkali in common glass being in a very imperfect state of combination, and the free alkali being obtainable from it. Faraday considered glass rather as a solution of different substances, one in another, than as a strong chemical compound; and that it owes its power of resisting chemical agents generally to its perfectly compact state, and the existence of an insoluble and unchangeable film of silica, or highly silicated matter, upon its surface. ("Bakerian Lecture," 1830.)

The origin of glass is uncertain. It is reputed to have been discovered by accident. This inference is strengthened by the fact that it is scarcely possible to excite a fire of sufficient heat for metallurgical operation without vitrifying parts of the bricks or stones of the furnace. Of such imperfect vitrification the "glass" occasionally dug up on the sites of buildings destroyed by great conflagrations is a specimen. (Apsley Pellatt, on "Glass-making.") Josephus claims the discovery for the Israelites. Herodotus and Theophrastus confirm the fact of the use of glass having been known in the earliest periods of civilisation, and of the establishment of glass-works in Egypt and Phœnicia, and even in India, where rock-crystal was employed in its composition. Glass is mentioned in the Book of Job: "Hast thou with him spread out the sky, which is strong, and as a molten looking-glass;" but this expression may have been intended, in the original Hebrew, to refer to the metallic speculum.

To the Phœnicians was long ascribed the discovery. It is stated by Pliny that "some mariners who had a cargo of *natrum*"—(salt, or, as some have supposed, soda)—"on board, having landed on the banks of the river Belus, a small stream at the base of Mount Carmel, in Palestine, and finding no stones to rest their pots on, they placed under them some masses of natrum, which, being fused by the heat, with the sand of the river, produced a liquid and transparent stream: such was the origin of glass." However this may have been, the sand which lay for half a mile round the river was peculiarly well adapted for the making of glass. The Sidonians, in whose vicinity the discovery was made, took it up, and in process of time carried the art to a high degree of excellence; they are even said to have invented glass mirrors. It is at the same time a curious fact in the history of discovery, that the manufacture of glass was, not many years since, unknown at Sidon, where it is reputed to have been first manufactured. Anciently, however, Sidon was famous for its glass. The above account by Pliny is, in substance, corroborated by Strabo and Josephus. Upon the above discovery Cuvier eloquently says:—"It could not be expected that those Phœnician sailors who saw the sand of the shores transformed by fire into a transparent glass should have at once foreseen that this new substance would prolong the pleasures of sight to the old; that it would one day assist the astronomer in penetrating the depths of the heavens, and in numbering the stars of the Milky Way; that it would lay open to the naturalist a miniature world, as populous and rich in wonders as that which alone seemed to have been granted to his senses and his contemplation; in fine, that the simple and most direct use of it would enable the inhabitants of the coast of the Baltic Sea to build palaces more magnificent than those of Tyre and Memphis, and to cultivate, almost under the polar circle, the most delicious fruit of the torrid one."

Upon no branch of invention have the researches into Egyptian antiquities thrown a stronger light than upon glass-making. Thus the discovery of a glass bead, with the name of a Pharaoh of the eighteenth dynasty, proves glass-blowing to have been known upwards of 3,200 years ago. Sir Gardner Wilkinson found at Beni-Hassan two paintings of glass-blowers at work, and from the hieroglyphics accompanying them, they are shown to have been executed before the exodus of the children of Israel, 3,500 years ago. In the same age the proper proportions of the ingredients for making glass were known. Lastly, the glass bead already mentioned is of the same specific gravity as our crown-glass. This relic Captain Hervey found at Thebes, and it bears the name of a monarch 1,400 years before Christ. Such was the skill of the ancient Egyptians in glass, making that they successfully imitated the amethyst and other precious stones. Winckelmann, a high authority, is of opinion that glass was employed more frequently in ancient than in modern times. It was used by the Egyptians for coffins; they also employed it not only for drinking-vessels, but for mosaic work, the figures of deities and sacred emblems on which were of excellent workmanship and superior brilliancy of colour. Wilkinson states that the Egyptians were always celebrated for their skill in glass manufacture: "Natron, or subcarbonate of soda, a native production in different parts of the country, was the very substance most likely to lead to its invention, or rather, to its accidental discovery; and it is far more reasonable to suppose that glass would have been made where natron abounded than from a fire accidentally lighted on the sea-shore by some

Phœnicians who happened to be carrying a cargo of natron." ("The Egyptians in the Time of the Pharaohs," p. 86.)

It would be reasonable to suppose that the Hebrews brought glass and a knowledge of its manufacture out of Egypt, were not the evidence of history so explicit that it was actually discovered and wrought at their own doors.

Archimedes is stated to have constructed an orb of glass for scientific purposes. Layard found, among the ruins of Nineveh, a microscope glass, a perfect goblet, which, from the characters on it and the locality in which it was found, is believed to be of the date seven centuries before the Christian era, and is probably the most ancient piece of manufactured glass in existence.

Beads which ornament mummies are not composed of glass, but of earthenware glazed. There can, however, be but little doubt that the Egyptians were well acquainted with the materials for making glass, or rather, with the metallic oxides for colouring it; since among the tombs of Thebes have been discovered small solid pieces of glass, or a turquoise, supposed to have been used for glazing the earthenware beads and figures. Fragments of blue, white, yellow, and green glass have likewise been found—possibly made by the Greeks and Romans who conquered Egypt. The manufacture of glass was long carried on at Alexandria, from which city the Romans were supplied with that material; but before the time of Pliny the manufacture had been introduced into Italy, France, and Spain. Glass utensils have been found among the ruins of Herculaneum and Pompeii, where glass was used for windows. The Pompeian and Roman architects used glass in their mosaic decorations; such as have been found among the ruins of the villa of the Emperor Tiberius, in the island of Capri, and are to be seen on the tomb of Edward the Confessor, in Westminster Abbey. Most of the large, greenish glass cinerary vases in the British Museum, found in Roman barrows, and which contained bones and bone-ashes, are probably the production of extensive Egyptian or Roman works; the glass is somewhat impure, and is not unlike the modern common crown or sheet glass in quality. Although remains of ancient Roman potteries have been exhumed in Great Britain, it does not appear that any traces of subterranean glass-houses or works have been discovered. Strabo relates that a glass-maker of Alexandria informed him that an earth (probably manganese) was found in Egypt, without which the valuable coloured glass could not be made. It is also related that the Emperor Hadrian received, as a present from an Egyptian priest, several costly glass cups, sparkling with every colour.

During the reign of Nero, great improvements were made in Roman glass. The clear glass which bore the nearest resemblance to crystal was so highly valued, that Nero is stated to have given, for two cups of no extraordinary size, the almost incredible sum of 6,000 sestertia, or nearly £50 000. The fired glass was in such extensive use in the time of Pliny, as to have almost superseded cups of gold and silver. Hence the manufacture chiefly of vessels of glass to imitate precious stones, cut by the lathe by Roman artists, or Greek artists resident in Rome, in the style of cameos in relief. In the British Museum are preserved many fragments of vases and white opaque enamel glass, upon blue and amethyst transparent grounds, supporting the probability of the above opinion. White crystal glass, without lead, cut to imitate rock-crystal, was also then known; and a few pieces of such glass of Roman manufacture have been found, their specific gravity being only 2·049, whereas flint-glass of the usual density is about 3·200 to 1·000 of water. Subsequently, other pieces of glass were exhumed in the city of London, considered to be ancient Roman—one small piece of 2·600, and another 3·144 specific gravity. Trade secrets in the preparation of glass for gems most likely existed in ancient times; for very little has been written by Egyptian, Greek, or Roman authors on the chemical constituents of glass gems, or cameo-engraved vases. Glass in solid pieces, such as gems and mosaics, was probably manufactured in small glass-houses. The glass-makers of Rome had a street assigned to them in the first region of the city; a tax was also laid upon them by Alexander Severus, which existed in the time of Aurelius, and probably long after. This was a sort of ancient excise, which is thought to have been one of the causes that transferred the glass manufacture to Venice. Glass was employed by the Romans as an ornament in their palaces, in decorating their altars, and for a pious offering in the tombs of the dead. Many fragments have been found in the catacombs, showing it to have been used likewise by the early Christians in their places of worship. In the reign of Tiberius, a Roman artist had, according to Pliny, his home demolished for making glass malleable. This secret is stated to have been re-discovered at St. Étienne, in France, in 1845, when glass was made as malleable when cold as when first drawn from the pot; by combining silicon with other substances, it can be obtained opaque or transparent as crystal, very ductile, neither air nor acids acting upon it. Professor Schœnbein (who invented gun-cotton) made also of paper-paste window-panes, vases, bottles, etc., impermeable to water, which may be dropped on the ground without breaking, and are perfectly transparent. In a Roman villa discovered at Boxmoor, Herts, has been found a piece of window-glass of greenish hue, and about three-sixteenths of an inch in thickness; its flat under-surface, and its hammered upper-surface, show this glass to have been manufactured by pouring it in a state of fusion upon a stone slab, and flattening it by repeated blows with a mallet.

The art of manufacturing glass into such ornaments as beads and amulets was certainly known to the Druids, and glass vessels were made by the Anglo-Saxons. Near Aberfrau Palace, in Wales, have been found Druid holy snakes, used as a charm to impose upon the vulgar; they are about half as wide as our finger-rings, but much thicker, and of various colours. Roman glass, with projecting pillars on the outside, and smooth interior, have been found in London; these pillars have been formed partly by moulding, and partly by rapid rotation, increasing the projection, on the principle of centrifugal force. Other Roman specimens of this kind are to be seen in the Museum at Boulogne-sur-Mer. "English glass-makers," says Mr. Pellatt, until this discovery, "considered the *patent pillar* (as it is called) to be a modern invention. A Roman vase thus made, and a complete specimen of pillar-moulding, is to be seen entire at the Polytechnic Institution."

The Aggry beads of Ashantee were found by Mr. Bowdich in that country, but the art of making them is entirely lost. Most of these beads appear to have been coloured in their layers, afterwards twisted together in a spiral form, and then cut across; also from different coloured clays, raked together without blending. How the flowers and patterns in the body and on the surface of the rarer beads had been produced, cannot be so well explained. In 1847, there were dug up at Cuddesden, the episcopal palace of the Bishop of Oxford, two small vases, of pale blue transparent glass, the pattern being produced by thick threads of glass applied to the surface while melted; these vessels are conjectured to be of the Saxon period, fifth or sixth century. In 1846, there was found at Headington, near Oxford, an ancient bead, of deep green glass, splashed with blue and white enamel thrown down on the mass when in a soft state; it was then probably slightly twisted, and its globular form flattened. A similar bead was found in the bed of a stream near the British camp of Medmarston, and is preserved in the Ashmolean Museum, with a curious series of beads, like modern green bottle-glass, marked with white and blue enamel. Here also are curious perforated beads, of various colours; some of the enamels being formed of concentric layers, and facets cut across these producing a variety of waved lines. Another has an imitation of stones of different colours, set in studs on its surface; and a third is ornamented with raised and twisted coral work. The whole collection in form, material, colour, and design, is very fine.

The Chinese have for ages been skilled in glass-making. Remusat states that their imitation of the precious stone yecchon was so excellent that it was almost impossible to distinguish the artificial from the real. It was manufactured into vases, some clear, transparent white, extremely brilliant, and as pure as a precious stone; others of beautiful blue, and equally pure. In Egypt and Syria, no difference was known between the real and artificial yecchon, the latter being of the same form, thickness, and specific gravity as the former. It is even asserted that at Cairo, and other cities, the artificial yecchon vases were as highly valued as the real. The Chinese have equally well imitated their ju-stone; it is coloured greenish, and of such hardness and weight that it frequently surpasses the real ju: fragments of it are erroneously denominated rice composition. A specimen of the artificial ju may be seen in the British Museum.

PRACTICAL PERSPECTIVE.—XV.

THE subject of the present study is introduced in order to show that so long as the plane of a circle or semicircle remains parallel to the picture-plane the form is not in any way altered, but is merely described with a shorter radius, varying according to the distance of the object from the picture.

Having drawn the front elevation of the two piers (Fig. 74), join them by the line D E, and from the centre C' describe the semi-circular arch; produce the external lines of the piers, and draw the top line of the elevation.

Now from A and A', *a a'*, D and E, draw lines to the centre of the picture, C.

From A set off A B equal to the real depth of the arch, and from B draw a line to the point of distance (not shown in this figure), cutting the line drawn from A to the centre of the picture in B'.

Through B' draw a horizontal line, cutting the line drawn from A' in B'', and cutting also those drawn from *a a'* in *b* and *b'*.

The lines *b* B' and B'' *b'* will represent the bottom lines of the other side of the piers, corresponding with *a* A and A' *a'* of the front elevation.

EXERCISE 78.

Scale, ½ inch to the foot. Height of spectator, 6 feet; distance, 14 feet.

There is a block of stone 5 feet square and 1 foot thick; there is a circular hole of 1½ foot radius pierced through the middle of it. Give a perspective view of this object when standing so that its square surface is parallel to the plane of the picture, at 3 feet on the right of the spectator.

EXERCISE 79.

Give in the same picture a view of the object when standing at 8 feet on the left of the spectator, and 6 feet within the picture.

EXERCISE 80.

Put into perspective the same object when lying on its square surface, so that one of the edges of the plan coincides with the picture-line, its situation being 6 feet on the left of the spectator.

EXERCISE 81.

Give a perspective view of the object when lying on its square surface at 7 feet on the right of the spectator, and 8 feet within the picture, its front and back edges being parallel to the plane of the picture.

In the next study an application of the projection is shown in the delineation of a viaduct.

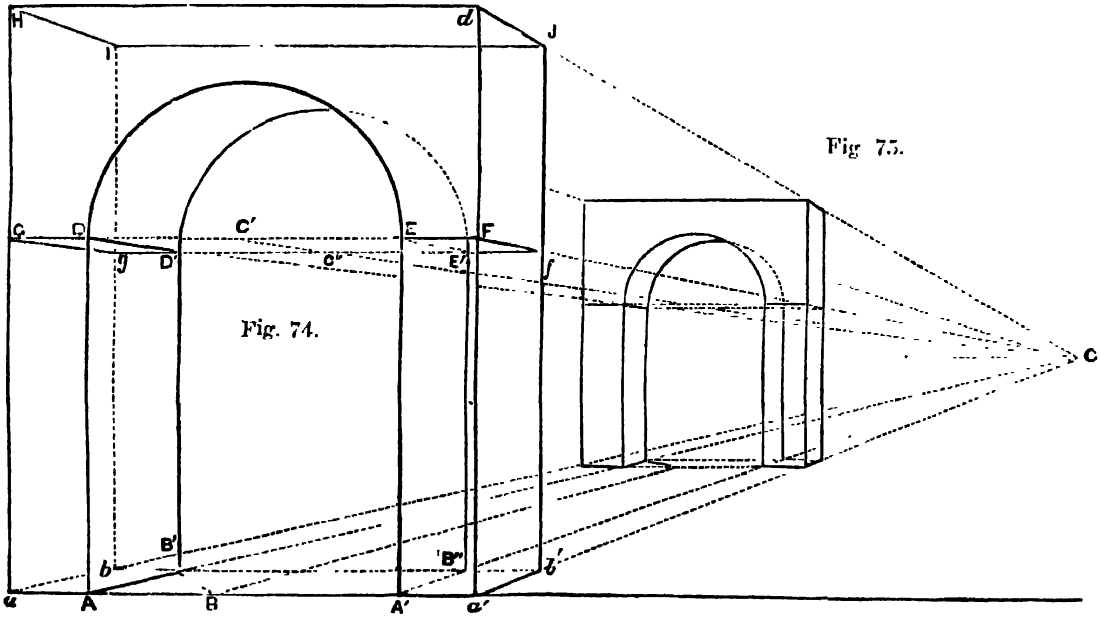

Fig. 74.

Fig. 75.

A perpendicular drawn from *b'* to meet a line drawn to the centre of the picture from *d* in the point J will complete the distant side of the object.

A perpendicular drawn from B' to meet the line drawn to the centre of the picture from D will give the point D', the springing of the arch of the back elevation.

Now from E draw a line to the centre of the picture, and from B'' draw a perpendicular, cutting the line drawn from E in E', the second springing point of the arch in the back elevation.

Draw the springing line, D' E'; then, if all the previous steps have been accurately followed, D' E' produced should meet a line drawn from F to the centre in *f*—that is, in the point where the line drawn from F cuts the perpendicular *b'*; and, similarly, it should cut a line drawn from G in *g*, the point where the line G intersects the perpendicular *b*. The perpendicular *b* should also, when produced, meet a line drawn from H to the centre of the picture in I, the point at which H is cut by a horizontal from J.

It now only remains to draw the distant semicircle.

From C', the centre of the arch in the front elevation, draw a line to the centre of the picture, cutting the springing line D' E' in C'', which point is the centre required.

From C'', with radius C'' E' or C'' D, draw the arch, the part which would be hidden being drawn in either a finer line than the rest, or in dots.

Fig. 75 shows the same object when at a distance within the picture.

The student will not find any difficulty in projecting the whole block, or the piers, and therefore, although all the working lines are given, it is not deemed necessary to give any instruction on that portion of the study, and we therefore proceed at once to the arches.

Fig. 76 is the geometrical elevation of the arch enclosed in the parallelogram A B C D. As the arch is a semicircle, this parallelogram will, of course, be half a square, the lines B G and C G will be the semi-diagonals, and the line G H the half-diameter, or height of the arch from the springing.

It will, of course, be evident that the lines A B and C D of Fig. 76 will in Fig. 77 be portions of the inner edges of the piers; therefore,

Having produced the nearest perpendicular, K, until it reaches L, the complete height of the structure, mark on it above A' (the top of the first pier) the height A' B', and from B' draw a line to the centre of the picture, cutting the inner edges of the piers M and N in B and C.

The intersections A and D will already exist, as the line from A' to the centre of the picture will have been drawn when projecting the piers.

The figure A B C D will then be the perspective projection of the containing rectangle.

Now, between the points on the picture-line which mark the real span of the arches, mark off the centre E, and from it draw a line to the point of distance, cutting the line drawn from K to the centre of the picture in F.

From F draw a perpendicular, which, cutting A D in G, will give the perspective centre, and cutting B C in H, will give the crown of the arch.

From B′ and A′ draw lines across the side of the first pier to *b*′ and *a*′, and from these draw lines to the centre of the picture.

Perpendiculars from *m* and *n* will cut these lines in *a b c* and *d*, which will be the projection of the containing rectangle on the opposite elevations.

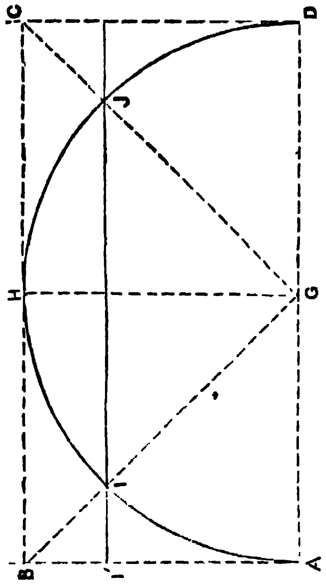

Fig. 76.

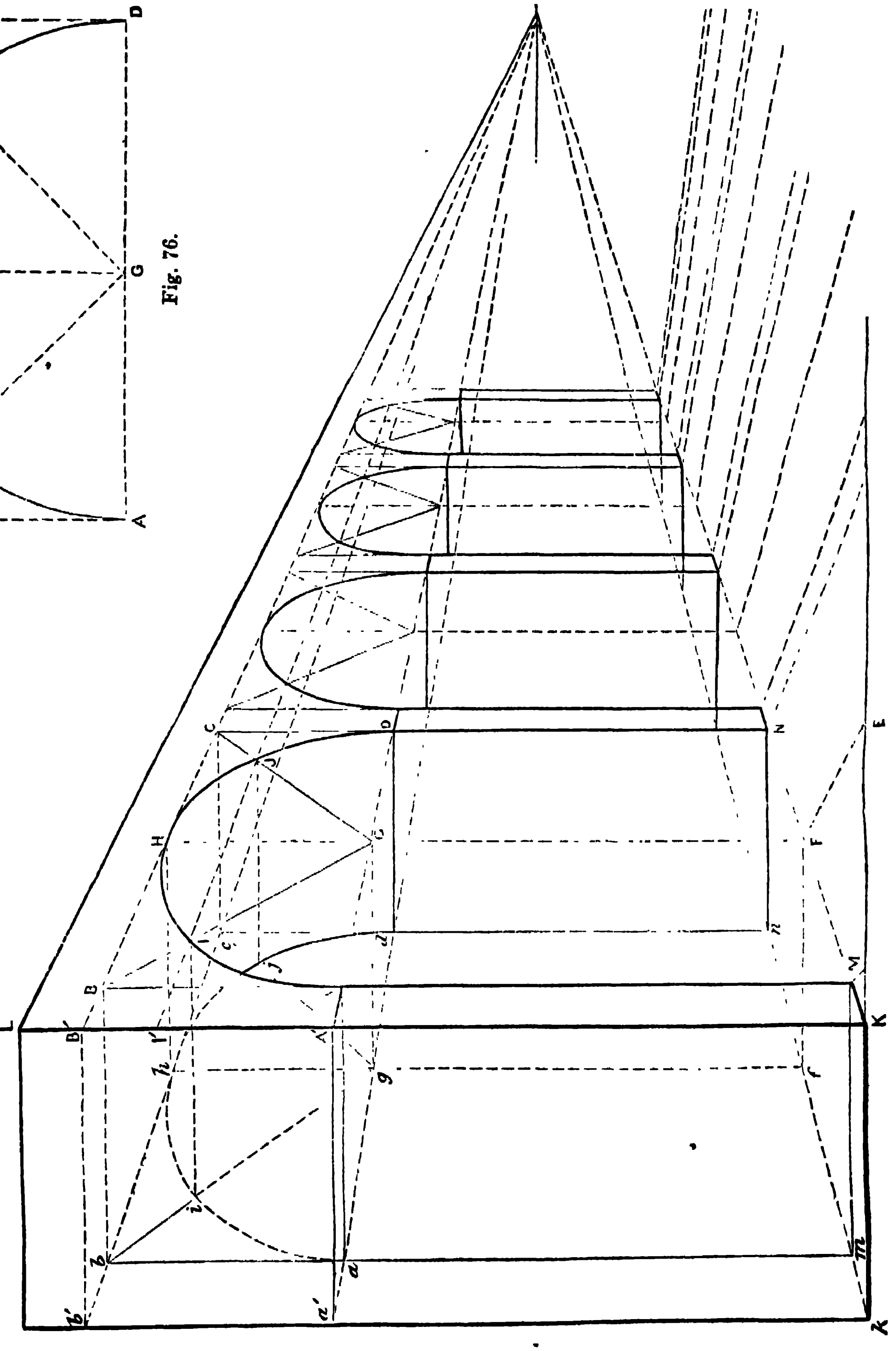

Fig. 77.

From F draw a horizontal line to *f*, and on *f* erect a perpendicular, cutting *a*′ *d* in *g*, and cutting *b*′ *c* in *h*.

Then *g* will be the centre, and *h* the crown of the arch, of the distant elevation.

Now draw the semi-diagonals B G and C G, and also *b g* and *c g*.

From A′ set off A I′, and from I′ draw a line to the centre of the picture, cutting the diagonals in I and J.

From I and J draw horizontals, cutting the semi-diagonals *b g* and *c g* in *i* and *j*. Now, starting from A, trace the curve of the arch, passing through I H J to D; also the corresponding curve, passing from *a* through *i h j* to *d*, the hidden portion being drawn either in dots or a fine line, whilst the part which is visible at *d j* is to be fully drawn.

This process is to be repeated for each arch, but the work will be materially lessened after the first has been drawn, as several of the lines already used will be available for all; and, further, as the arches recede, those on the opposite elevation will become invisible, and it will therefore be unnecessary to draw them, excepting for special study.

EXERCISE 82.

Put into perspective the series of arches similar to those shown in

Figs. 74, 75, when the front elevation is placed at 50° to the plane of projection. The scale, height of spectator, distance, and dimensions at pleasure.

The limits of these lessons preclude our carrying this subject any further; but the student is urged to remember that this series of lessons is merely elementary, and that it is want of space, and not want of matter, which compels us to close. Each lesson herein given, however, is capable of further working out, and it is hoped that every learner will endeavour to vary and apply the studies so as to acquire a thorough knowledge of the subject as far as taught in these pages, and he will thus prepare himself for the advanced courses specially adapted to the various branches of industry which will diverge from this.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVII.—JOHN ROEBUCK, M.D., F.R.S.

BY JAMES GRANT.

Dr. John Roebuck, one of England's greatest experimentists in metallurgy and chemistry, and who, had he fully succeeded as projector of the great Carron Ironworks, would have been deemed one of Scotland's greatest benefactors—"one who, during a long and active life, was distinguished by uncommon talents and great virtues"—was born in 1718, at Sheffield, where his father carried on the business of cutler, in the course of which he realised a comfortable competency. Pleased with his success in life, he wished his son to follow his own trade, but the lad being irresistibly attracted to something higher than mere dealing in hardwares, and having a love for science, was liberally encouraged in his tastes by his father. He was thus sent to Northampton, and placed under the tutelage of the Rev. Philip Doddridge, who there taught classical literature, logic, ethics, theology, and some collateral branches, and who had then among his pupils Hugh Farmer, afterwards known by his writings. Dr. Aikin, the father of Mrs. Barbauld, was one of his assistants, and his lectures were attended by students even from Scotland and Holland. From this provincial seminary he was sent to the University of Edinburgh, where he applied himself to the study of medicine, but more particularly that of chemistry, which was then the subject of much attention at all the Scottish universities. While in Edinburgh he contracted many friendships (which were useful to him in after life) among the men of letters for whom the North was then famous, particularly Hume and Robertson, the historians; and "this circumstance is supposed to have contributed not a little to his partiality in favour of Scotland, and his afterwards selecting it as the field for his industrial operations."

After studying and graduating at Leyden, in 1745 he settled at Birmingham, which then consisted of little more than thirty small streets; but it was in that year that Boulton's invention for inlaid steel for buckles, watch-chains, and other articles was there brought to perfection; and, even then, Birmingham was the principal seat of the metal manufacture, and its mechanics were deemed among the most skilful in Britain. While practising his profession, the attention of Dr. Roebuck was drawn at an early period to the extreme scarcity and high price of the material in which the tradesmen worked, and he conceived that a method might be devised to smelt the iron otherwise than by charcoal. He had a laboratory fitted up in his house for the purpose of prosecuting inquiries with this end in view, and at the crucible he spent every hour he had to spare from his professional duties. It was thus that, like Dudd Dudley in the preceding century, he came upon the same process of smelting iron by pit-coal, and afterwards had it embodied, like that luckless cavalier-projector, in a patent. He invented also new and improved modes of refining gold and silver; and these proved of vast practical value to the mechanics of Birmingham in their various branches of trade.

Roebuck next sought to invent the most economical modes of procuring the different chemical forces, such as ammonia, sublimate, and other acids, used in the Birmingham trade; and so great was his success in these efforts that he was induced to build a large laboratory for their manufacture, and this his friend Mr. Garbett conducted with great skill. His success led him to project the establishment of a large manufactory for the modern process of distilling vitriolic acid in larger quantities, and in leaden in lieu of glass vessels; and having now relinquished his practice of physic, and taken as a partner Mr. Garbett, he resolved to establish his new works in Scotland, and with this view repaired to Prestonpans, a melancholy old burgh then and now, hastening to ruin, situated somewhat bleakly, on the south bank of the Forth. There, in 1749, he built his projected works, and the enterprise proved so successful and lucrative that he resolved to strike out new branches, and started a pottery, which exists to this day, in the same neighbourhood, for the manufacture of white and brown earthenware. The clay used in this work was brought from Devonshire; the flint from Kent; the red and white lead from London and Hull.

About this time he had the good fortune to make the friendship of Mr. Cadell, of Cockenzie, a neighbouring proprietor, who was earnestly intent on developing the industries of Scotland, which were then in a very backward condition, and for long after were crushed by centralisation and imperial neglect. Cadell had frequently endeavoured, without success, to establish a manufactory of iron; but, on being joined by Roebuck, they proposed to organise a company, select a site, and make the necessary arrangements for beginning the smelting of iron. A careful examination of the coasts of Fife and Lothian led Roebuck to select a spot on the then sequestered banks of the Carron, near Larbert, in Stirlingshire, where there was a plentiful flow of water, and in the neighbourhood an inexhaustible supply of iron, coal, and limestone; and there, on that ground which Scottish history and tradition have made alike classic, Dr. Roebuck planted the first Scottish ironworks, and there the first furnace was blown on January 1st, 1760.

Skilled workmen, who were brought from England by Roebuck, formed the nucleus of industry there; and in the course of the first year the works turned out 1,500 tons of iron. The original capital was £150,000, divided into 600 shares; and by the year 1772, 2,000 men were employed there. The operations carried on within were long kept a secret from the outer world, and hence the rule which excluded Robert Burns when he went to view the place—a rule which still exists to a great extent. In accordance with his patent, dated 1762, the doctor used pit-coal, and thus describes his process:—

"I melt pig or any kind of cast-iron in a hearth heated with pit-coal by the blast of bellows, and work the metal until it is reduced to nature, which I take out of the fire and separate to pieces; then I take the metal thus reduced, and expose it to the action of a hollow pit-coal fire, heated by the blast of bellows, till it is reduced to a loop, which I draw out under a common forge hammer into bar-iron."

The principal production of the Carron Works was castings, for which the peculiar quality of the Scotch iron admirably adapts it.

In 1771 the projector had the misfortune to lose his brother, Mr. Ebenezer Roebuck, a merchant of London, and partner in the company, who, while viewing the Carron Works, was crushed to death by a vast piece of iron which fell upon him.

The ship and battery guns so long and well known as carronades or "smashers" were first cast here in 1779—the invention of General Robert Melville, an officer who served under Lord Rollo at the capture of Dominica, the storming of Martinique, and elsewhere. They were peculiarly constructed, being shorter and lighter than other cannon, and having a chamber for the powder, like a mortar. They were cast in enormous numbers at Carron, and were employed throughout all the fighting and mercantile marine of Europe and of America. The first of them was presented by the Carron Company to the family of the general, who still preserve it; and an inscription on the carriage records that they were cast for "solid, ship, shell, or carcass shot, and first used against the French fleet in 1779."

Wealth was now flowing in for a time upon Dr. Roebuck, who embarked in coal-mining, and became the lessee of the Duke of Hamilton's great mines at Borrowstowness, as well as the salt-pans in connection with them. He then, with his family, leased one of the duke's country-seats, named Kinniel, a stately old chateau, situated on the edge of a beautiful bank fifty feet above the Forth, surrounded by gardens and great old trees, and commanding a fine view of the whole estuary and coast of Fife.

In sinking for coal at the new mines, he found a necessity for pumping machinery of the most powerful kind to keep them clear of water; and Newcomen's engine being found insufficient for that purpose, his friend, Professor Joseph Black, who then occupied the chair of chemistry at Edinburgh, and is celebrated as the discoverer of fixed air or *carbonic gas*, informed him "of a young man of his acquaintance, a mathematical instrument maker in Glasgow, who had invented a steam-engine calculated to work with greatly increased power, speed, and economy, compared with Newcomen's." Roebuck was much interested on hearing this, and immediately wrote to "the young man" in question, who proved to be no other than James Watt! He was invited to Kinniel, whither he came in the month of May, 1768, and Roebuck was so pleased with his engine and mechanical genius, that the subjects of its introduction to general use, and of his becoming a partner, were speedily discussed. Watt, who, as we have related in his memoir, had been labouring at his invention for years, contending with the difficulties incident to limited means, and was deeply indebted to Professor Black, whose monetary advances "he had felt to hang like a millstone about his neck," hailed with pleasure the patronage of Roebuck—one accustomed to great enterprises, "a bold and undaunted man, and disregardful of expense when he saw before him a reasonable prospect of success. His reputation as a practical chemist and philosopher, and his success as the founder of the Prestonpans Chemical Works and of the Carron Iron Works, justified the friends of Watt in thinking that he was, of all men, the best calculated to help him at this juncture, and hence they sought to bring about a more intimate connection between the two. The result was that Dr. Roebuck eventually became a partner to the extent of two-thirds of the invention, took upon him the debt owing by Watt to Professor Black, about £1,200, and undertook to find the requisite money to protect the invention by patent. The necessary steps were taken accordingly, and the patent right was secured by the beginning of 1769, though the perfecting of his model cost Watt much further anxiety and study."

It was in an outhouse, still standing at Kinniel, and close behind the old ducal mansion, by the burnside in a wooded glen, that Watt worked till he brought his engine to perfection, and his somewhat desponding spirit was always cheered the while by the hopeful nature of Roebuck.

In the course of his useful and public-spirited exertions, the latter met with many pleasing and flattering marks of approbation from the most distinguished men in the country; and the magistrates of Edinburgh, when he was presented publicly with the freedom of the city, stated "that they granted it to him for the eminent services he had done to Scotland." The Carron Works still employ more than 2,000 men; there are five blast or smelting furnaces, four cupola furnaces, and twenty air furnaces. Besides the machinery driven by water, there is a steam-engine of 90-horse power, which is used entirely in the production of blast. All kinds of cast-iron goods are manufactured there—cannon, mortars, carronades, shot, shell, agricultural implements, pipes, boilers, ovens, vats, pots, etc.

When Roebuck's speculations were at their zenith, misfortunes began to come upon him; and when the fatal crash came, *he* sank under the burthen, and not Watt. The progress of the latter's engine was slow, and as it was long before it could be applied to draining the mines, the heavy responsibilities of Roebuck were proving too much for him. The opening out of the principal coal involved an enormous outlay: it had extended over years, during which the bold English speculator sunk not only his own fortune, but that of his wife, and large sums borrowed from many friends—a resort that distressed him deeply—all of which he was eventually totally unable to repay or to retrieve. Yet he struggled hard and nobly. From his refining works at Birmingham and his vitriol works at Prestonpans he withdrew his entire capital; while at the same time he transferred to Watt his entire interest in the steam-engine, "the value of which was thought so small that it was not even included among the assets; Roebuck's creditors not estimating it as worth one farthing!"

Roebuck did not long survive his pecuniary misfortunes; after a little time spent in comparative obscurity, he died at Kinniel House, July 16th, 1794, in his seventy-sixth year. From Kinniel, according to the *Scottish Chronicle*, "he was carried to the place of interment in the churchyard of Carriden, on the 19th, amid the silent and respectful sorrow of many hundreds of his workmen and their families."

By a chance in the turn of events, his native town of Sheffield was long represented in the British Parliament by John Arthur Roebuck, his grandson; but such was the energetic career of one whom a recently published Cyclopædia of Biography dismisses thus with two pithy lines:—

"Roebuck, John, a physician and experimental chemist, born at Sheffield in 1718; died, after ruining himself by his projects, 1794."

PRACTICAL APPLICATION OF THE FINE ARTS.—IV.

THE ART OF GLASS-PAINTING.

By P. H. Delamotte, Professor of Drawing, King's College, London.

CUTTING OUT, SHADING, AND BURNING THE GLASS.

Matching Colours.—We have spoken of the manufacture of pot metal; the next process is to prepare this pot metal for the picture. The first thing necessary is to make choice of the glass to be used, and for this purpose it is convenient to have a frame fixed with small pieces of glass of various colours and different manufactures; and this frame hung before a window with a good light, looking to the north, and not obstructed by houses or trees, but so placed that the glass can be seen against the clear sky, gives an opportunity of matching the colours with those of the original design. In this matching the colours it must be remembered that the plain glass should approach most nearly to the tint of the brightest part of each colour, as the subsequent shades will make the colour darker and somewhat duller; though the aim of good painting is to avoid as much as possible dulling the original colour. But whatever care may be taken to match the glass by specimen pieces, after all the actual sheets of pot-metal must be taken out and examined to choose those sheets which, from their thickness, depth of colour, imperfections, and shading of tint, are suitable to the subject in hand.

Cutting out.—The glass being chosen, it is laid upon the working drawing or cartoon, and with a diamond cut to the required shape. The ancients, who did not use diamonds (and we do not know that the use of the diamond was discovered before the time of Queen Elizabeth and Francis I., and it was not commonly employed in cutting until 1700, though perhaps some scratching had been done at an earlier period), had to adopt other methods, and elaborate directions are given in old treatises how the glass might be divided. From this imperfection of instruments we may explain some of the more frequent leadings which we find in a great many of the old windows; though, no doubt, much more is to be accounted for by mending subsequent upon cracking. The English plan of having a charcoal drawing upon white paper is preferable at this stage to the French habit of drawing on a blue paper; since the black lines on the white are clearly visible through the semi-transparent glass, whereas the drawing on a blue paper has to be traced on the glass before the latter is cut.

When the glass is cut into a proper shape it is roughly clamped together with bits of leading or lumps of cobbler's-wax, and hung up, so as to represent the intended picture in general outline.

Painting.—The shading now begins. This is effected by a process of enamelling; that is, the surface of the glass is rendered less transparent by the use of metallic oxides. What is technically called *staining* is an entirely different process, though apparently the means are the same. Staining implies the imparting a yellow, orange, or similar colour through the depth of the glass without detracting from the transparency. The enamelling is burning into the surface of the glass a metal which, while it imparts some colour, at the same time destroys more or less completely the transparency of the material. The great art in painting or enamelling is to overcome this difficulty of destroying the transparency, as may especially be seen, either in those miserable failures of foreign workmanship in St. Paul's Cathedral or at Glasgow; for with glass of even greater transparency than the English the Continental glass-painters contrive to make opaque pictures instead of transparencies. It was against this that the late Mr. Winston so earnestly warned modern glass-painters.

Materials.—The materials used in enamelling are principally oxides of iron, both red and black; and with these are used sometimes red or white lead, the whole being mixed with silica and borax. The various materials used give a variety of colour to the shade, and judgment must be used to adapt the tone to the result required. The materials can probably be best obtained from some glass-painter, until the artist becomes a little accustomed to the use of them. They are mixed with various vehicles, either water or oil. If water is employed, a little gum should be added to stiffen the pigment. The oils used are turpentine, oil of lavender, oil of thyme, and tar. It is usual to use water in the earlier process, and to finish off with oil. The implements used are given in Fig. 2. They consist of one or two flat sables, No. 4; a stippler made of hog's hair, No. 1; a tracer of sable, No. 2; a scrubb, Nos. 3 and 5, made of hog's hair cut down from an ordinary oil-colour tool, either round or flat, the latter being better; and a shader for oil colour. This last may be either sable or camel's hair.

Kinds of Shading.—The various kinds of shading are called (1) the smudge or smear, (2) stippling, and (3) line-shading. The whole of these three kinds of shading are frequently used in the same window. 1. The smear is applied with a large soft brush, No. 4; of course, not flat all over alike, but deepest in those portions where the shadow is to be darkest; but this is much improved if it is stippled with such a brush as No. 1. This is done by pushing the end of the hairs against the glass and withdrawing the tool quickly. By this means the pigment, instead of lying in flat sheets or in streaky lines, is drawn up into dots and short strokes, leaving interstices through which the light can penetrate. When this first shading is dry it will be possible to rub off the pigment, which has become powdery, from those parts that should be quite light. This may be done either with such a brush as Nos. 3 or 5, or with the handle of the brush or other convenient stick. After this it will be useful to apply more shade, and this is usually mixed with an oil vehicle, either as before with stippling, or by tracing lines of some considerable force with brush No. 2. When the outlines are strongly marked it will frequently be found convenient to trace out these first with No. 2, and afterwards to add the stippling when the former is dry. The early painters of the twelfth century not unfrequently rested entirely upon the force of their line-shading, and seldom used stippling. In the case of stippling or smear-shading with an oil vehicle it will be found advantageous to lay on a thin coating of oil or two previously, in order to make the colour work more easily.

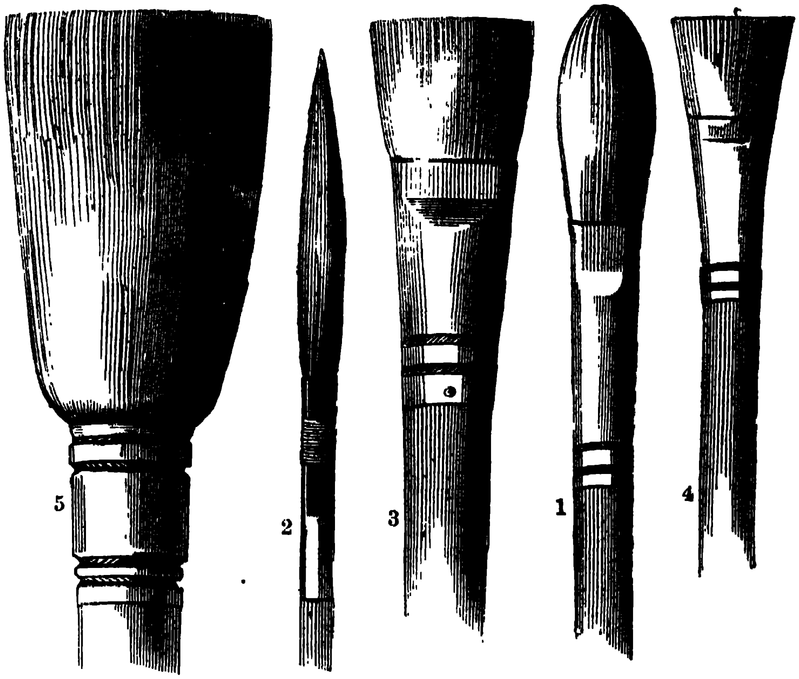

Fig. 2.—BRUSHES USED IN GLASS-PAINTING.

Practice in chalk-drawing will assist the artist towards a mastery of the character of shading required for glass-painting. The general shades put in with the stump answer to the smear and stippling, whilst the firm black lines added afterwards correspond with the shades produced with the small fine brush.

With the *flashed* glasses, which are almost all of a ruby colour, with either white (*i.e.*, transparent), or light brown, or yellow foundation, another treatment is sometimes adopted; the flashing is removed either with fluoric acid or by grinding—in glass-painting almost always by the former process. The plain glass thus left can again be stained with nitrate of silver, or shaded like other glass.

Effects of Shading on Different Coloured Glasses.—It will soon be found that different coloured glasses receive the shading differently. Delicacy of shadow and half-tints would be entirely lost upon deep and heavy glass; whereas on flesh tints, white glass, and other pale tints, great variety and delicacy can be used. The shading, again, after it is burnt seldom appears so deep as it did when the unburnt pigment lay on the surface; but in this respect there is considerable difference in different glasses.

Grisaille.—In the above we have entered into all the processes of staining and shading every kind of glass; but the beginner will find that the sort of glass-painting called grisaille will afford him considerable scope for the employment of his talents, and yet not be so complicated as where a great variety of colours are combined. This consists of brown patterns or scroll-work, accompanied by yellow stain upon white glass.

Burning.—The glass being thus painted, it is ready for burning, and this is accomplished in furnaces fitted with shelves or drawers of iron, covered with lime finely powdered. On this lime the glass is placed, and the whole subjected to considerable heat, but not sufficient to melt the glass, only enough to soften it. During this process the silver sinks through the plates of glass, whilst the shade is attached to the surface so finely that it cannot be detached. Either through defective burning or from the chemical action of various gases upon the surface of the glass, the shade will not unfrequently come off old glass if only scratched with the nail. A good deal of care and watchfulness is required to heat the glass to the required temperature so as not to melt it on the one hand, and on the other to ensure the fixture of the colour.

The glass may be burnt several times over, but it is better, if possible, to arrive at the desired effect in one burning, for not only does this save time—a matter which should always be a consideration with the "cunning workman"—but it imparts a greater transparency and brightness to the glass.

Leading.—The glass being now completed, it is all ready to be fastened together with the leads. These leads are in something of the form of an H placed sideways, thus ⌶. The workman takes a piece of the glass, and cuts off a portion long enough to go completely round it. He then bends it round the corners, and presses in the lips of the folds. When it is fitted, the chinks between the lead and the glass are filled up with putty or cement, and the joints are soldered together. Care is taken to fix little wire hooks to such parts of the leading as will come against the stanchions, and the whole is completed and fit to be raised to its appointed place.

The Proper Study of Antiquity.—In this matter of leading, as in almost all other points connected with painted glass, the work of the ancients and of the moderns should be observed; the former with a view of imitating the different modes by which various difficulties should be overcome, at the same time avoiding the peculiarities which their ignorance of many modern inventions made compulsory; the latter, that their deficiencies, carelessnesses, and want of taste may become a warning of shoals and rocks upon which the competition and aim at cheapness of modern times have shipwrecked many an intelligent workman and many a painstaking artist. The leads of the ancients were narrow but strong, scarcely perceptible in the pictures; whereas those of the last and the early part of the present century were broad and disfigured the glass. The present manufacturers, in this respect as in many others, are doing their best to cultivate a wise and discriminating imitation of antiquity.

THE STEAM-ENGINE.—XII.

By J. M. WIGNER, B.A.

THE LOCOMOTIVE — SPECIAL REQUIREMENTS — FURNACE — TUBULAR BOILER — MECHANISM — REVERSING GEAR — GOODS ENGINES.

We have reserved for this our concluding paper a description of the locomotive, which is one of the most important applications of the power of steam. In modern times the whole of this and several other countries has been intersected by various lines of railway, and there are scarcely any countries entirely devoid of them. In many places, indeed, they have performed a very important office, having served as the pioneers of civilisation, and opened up fresh fields for industry and commerce.

In India their influence in this way has been much felt, and hence the system there is at the present time being greatly extended.

This rapid development of the railway system has very naturally directed much attention towards the best and most economical form of steam-engine suitable for working it. The plan of employing a fixed winding-engine with a long rope attached to the carriages was soon found to be costly and unsatisfactory, and at the present time locomotives of various kinds are employed on all passenger lines, the old plan being still retained on a few mineral lines with steep gradients.

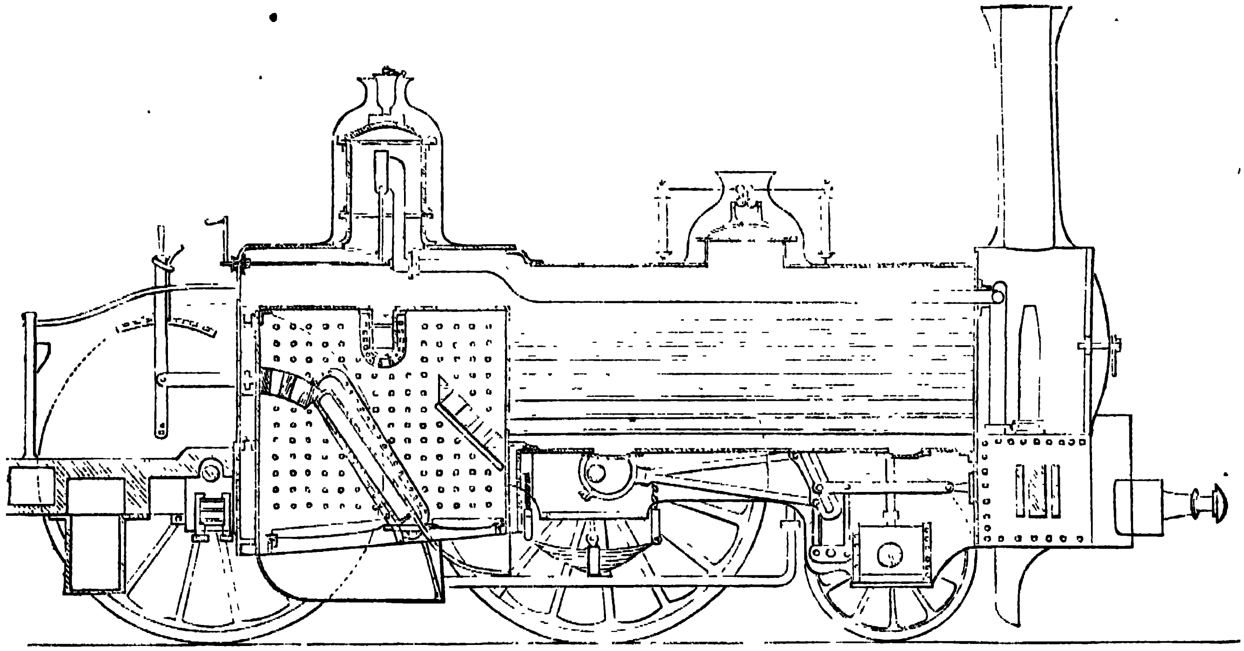

Fig. 45.—SECTION OF EXPRESS PASSENGER LOCOMOTIVE ENGINE.

On all long and important lines there are two perfectly distinct kinds of traffic, the one consisting of passengers and parcels of light weight, the other of heavy goods and parcels. For the former of these the greatest rate of speed that can safely be attained is desirable, and passenger engines are accordingly constructed capable of drawing light loads at a speed of at least 50 or 60 miles per hour. For the goods traffic engines of a much more powerful form are constructed; these possess greatly increased tractive power, but travel at a slower pace than passenger engines. On some of the Continental railways, goods engines of a very cumbrous and complicated construction have of late been introduced, some of them possessing as many as six pairs of driving-wheels, and four cylinders. It seems probable, however, that the same duty might be more efficiently and economically performed by the employment of two ordinary goods engines coupled together, when such very heavy trains are required.

There are many things which have to be considered in the construction of a locomotive. Its various parts must be made very strong and securely fastened together, to enable it to resist the constant vibration arising from the rapid motion. The boiler is also limited in diameter by the distance between the wheels, as it is very inconvenient for it to overhang them; and its dimensions being thus limited, various arrangements have to be made to enable a sufficient amount of steam to be generated.

The engine has also to be so constructed as to carry with it a supply of fuel and water sufficient to last it for the journey, or till it arrives at some station where it can be replenished. In engines which run on the long lines of railway a separate tender is usually provided to hold these, and is coupled closely behind the engine. In those, however, which run short distances—as, for instance, on many of the metropolitan lines—the tender is dispensed with, a small tank and coal bunker being arranged at the hinder part of the engine.

Considerable arrangement is requisite to ensure the due distribution of the weight on the various wheels: the greater portion should rest on those which drive the engine, as they thus obtain a much firmer grip on the rails. Great fears were at first entertained lest this grip should prove insufficient to propel a heavy train, but experience has now completely dissipated these. In frosty weather there is occasionally a difficulty at starting, but a little sand or gravel scattered on the rails soon overcomes this, and in most engines a small sand-box with a shoot is now placed at the side so as to scatter a little sand in this way when necessary.

The great object that has been aimed at of late is to construct a locomotive which shall burn coal, and at the same time consume its own smoke. All engines are now required by law to burn coke in order to avoid the injurious effects of the smoke, but this adds greatly to the expense, coke being much less economical than coal as a source of heat.

In Cudworth's engine the furnace is made very long and sloping, and only a thin layer of fuel is laid upon it. The coal is then gradually supplied in front, and the smoke is mainly consumed as it travels over the incandescent fuel beyond and becomes mingled with the air that enters through the fire-door.

Other engines are fitted with a combustion-chamber beyond the furnace, and in this the flame and gases become mixed with air and consumed. In Beattie's form there are two furnaces so arranged that the products of combustion in the lower shall pass over the other, and thus be consumed before they reach the flues. In this case the upper furnace is fed with coke, while the lower may be fed with coals, as the smoke given off from it is consumed in passing over the coke fire.

Very many other plans have been tried with varying degrees of success, but none can yet be said to have fully attained the desired end, though the amount of smoke evolved is materially diminished by their adoption.

The general construction of the locomotive will be best understood by means of a sectional view. We have accordingly given one of an express passenger-engine with coupled driving-wheels, similar to many in use on the London and North-Western line at the present time, and we shall proceed to explain in succession the details of the various parts (Fig. 45). The furnace here shown is constructed on Beattie's plan, being divided into two portions by a sloping water-bridge which passes from side to side of the furnace. The smoke from the lower or hinder furnace passes through perforations in this bridge, and in the fire-block against which it leans, into the second furnace. A hanging bridge at the top of this deflects the smoke downwards on the burning coke, and thus ensures its being consumed, while a second perforated bridge placed at the back of the fire-box prevents the heated gases escaping too rapidly into the flues. The sides of the fire-box are made double, the water in the boiler being allowed to circulate in the space between the two plates, and much heat is thus imparted to it. Various stays connect these two plates together so as to prevent their bulging, and some of these stays are made hollow so as to increase the heating surface of the fire-box.

Movable ash-trays are placed under each of the furnaces to receive the hot cinders that fall from them, and levers are usually provided by which the doors of these ash-pans may be opened, and the cinders allowed to escape.

The barrel of the boiler below the water-line is occupied by a large number of tubes, usually made of brass, and securely fastened to the back of the fire-box, and in front to a plate fixed in the end of the boiler. The smoke as it passes through these imparts to the water the greater portion of its heat, and then escapes into the "smoke-box," as the front portion of the engine directly under the chimney is called. The tubes are of small diameter, usually about 1¾ or 2 inches, and are placed as close as they well can be, when sufficient room is left for the circulation of the water between them.

In the front of the engine is a door which opens into the smoke-box; sometimes this is made in one piece, and can be removed entirely, being held in its place by a screwed bolt and nuts; at other times it is made in two pieces hinged at each side. By opening this, access is gained to the smoke-box for the purpose of removing soot or ashes which may be deposited there, and also to clean out the tubes.

The funnel of a locomotive must of necessity be somewhat short, to admit of its passing under the various bridges which so often cross a line of railway. This fact, coupled with the small diameter of the tubes, tends to render the draught somewhat feeble, and hence there was at first difficulty in maintaining sufficiently rapid combustion in the furnace. This is entirely overcome by allowing the exhaust steam to escape into the chimney. The two exhausts are connected by a Y, or, as it is termed, a breeches-pipe, to one mouthpiece; and the constant escape of the steam at a considerable pressure from this quickens the draught very greatly, and produces the snorting or puffing so well known to all who have observed an engine at work. This jet is usually carried a little higher than the mouth of the uppermost layer of tubes.

On the top of the engine are seen two domes. The front and smaller one of these is fitted with two safety-valves, one of which is usually secured so that it cannot be altered by the engineer. A valve is also frequently fitted at the top of the other dome, but the main purpose of this is for the mouth of the steam-pipe to open in it. The higher this can be made to open above the surface of the water in the boiler the better it is, as the ebullition, added to the shaking of the engine, keeps a larger amount of water mechanically suspended in the steam space, in a state of minute division. If much of this were allowed to enter the steam-pipe, there would be an excessive amount of priming. As it is, the blow-off cocks in the cylinder have to be frequently opened to allow of the escape of the condensed water.

The mouth of the steam-pipe is therefore situated near the top of the dome, and is closed by a valve which is regulated by the handle seen over the furnace-door. Sometimes a valve of ordinary construction is used for this purpose, but more frequently there are a number of parallel slots at the mouth of the pipe, and against these a gridiron plate, cut with corresponding slots, works steam-tight. The degree to which the valve is opened is capable of exact adjustment by means of the handle, the motion being usually communicated by means of an eccentric fixed on the rod, and thus the engineer can increase or diminish at pleasure the supply of steam to the cylinder.

The steam-pipe passes along inside the boiler, and through the end of it by a steam-tight joint into the smoke-box, where it divides into two branches, one of which goes to each cylinder.

The cylinders are situated at the lower part of the smoke-box, often being included within it. In the engine figured their diameter is about 17 inches, and the stroke nearly 2 feet. The head of the piston-rod is made to work between guides firmly secured to the frame-work of the engine, and a connecting-rod passes from this head to a crank which is forged on the axle of the driving-wheels. A straight connecting-rod also passes from a crank fixed to the end of this axle outside the wheel to a similar crank fixed to the axle of the hinder pair of wheels, so that there are four driving-wheels instead of two, and in this way a much greater hold on the rails is obtained. These wheels must, of course, have exactly the same diameter, and the cranks on their axes must be similarly placed. In the engine shown their diameter is 7 feet, and they are about 5 inches in width; a few are made even larger than this, but the usual size in ordinary passenger engines is from 5 to 6 feet. A small flange is turned on the inner edge of all the wheels to keep them from running off the rails.

The connecting-rods and guides are not shown in the figure, as they would only render it more complicated.

We come now to a very important point, namely, the slide-valve, and the means of controlling its movements in such a way as to make the engine travel forwards or backwards at pleasure. The valve itself is of the ordinary three-ported kind, and an eccentric fitted to the axis of the driving-wheels imparts motion to the valve-rod. A moment's thought will at once show that the direction in which the engine moves depends upon the position of the eccentric with regard to the crank. Suppose, for instance, that the piston is at the middle of the stroke when the steam is turned on, and that the crank is situated at the same time above the axis; then if the valve be in such a position that the steam is admitted to the top of the cylinder the engine will travel forwards, while if it be admitted to the bottom it will travel backwards. Now the position of the valve will manifestly depend upon that of the eccentric, and this it is almost impossible to make movable. The difficulty is, however, fully met by fitting two eccentrics to the axis, one in such a position as to propel the engine forwards, the other to propel it backwards, and the rods from these two eccentrics are connected to the two ends of a link, as shown on a larger scale in Fig. 46. Here F is the forward and B the backward connecting-rod, and V the valve-rod, the end of which, A, moves in the link. When in the position shown the motion of B is transmitted to V, and the only effect of F is to make that end of the link oscillate. If, however, we depress the link so that A is at the other end, the engine will travel forwards. This link is moved by means of the lever seen behind the handle for turning on the steam, and thus we can depress or elevate the link as we please, and cut off the steam at any required part of the stroke. In our section only one link is shown, but one is of course required for each cylinder, and thus there are in all four eccentrics and two links. Both links are, however, moved by the same lever, and in the quadrant seen behind it there are a series of notches, by which it may be locked in any required position.

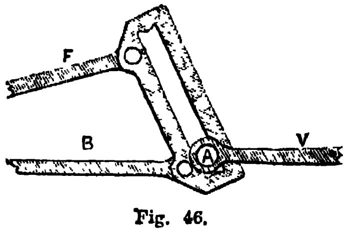

Fig. 46.

The boiler is fed from a tank situated in the tender, and the water is supplied by the pipe seen passing along under the boiler and fire-box. Sometimes the engine is fed by a force-pump, but Giffard's injector is now very generally employed. In nearly all cases the boiler is fed with cold water, all the waste steam being allowed to escape into the chimney. Occasionally, however, a portion is condensed, and the temperature of the feed-water raised in this way. This plan is adopted in many engines on the Metropolitan Railway.

In a few engines which run long distances, an arrangement is made by which a fresh supply of water can be taken into the tender while the engine is in motion.

A long narrow trough is placed between the rails, and filled with water to a depth of four or five inches; a scoop is then attached to the under side of the tender; this can be lowered at pleasure; and as it passes along, it dips into the water and throws it up into the tank, the speed at which the train travels being quite sufficient to raise the water.

Under the cylinder is seen a piece of iron which comes nearly down to the level of the rails, and serves to remove any obstacle which may accidentally be present on the line. In most American locomotives this is replaced by a large guard of iron rods extending a little way in front of the engine, and known as a "cow-catcher," and in snowy weather this is sometimes fitted with a "snow-plough."

Goods engines are usually made of a heavier and stronger form. The driving-wheels are of less diameter, and two or sometimes three pairs are connected together so as to increase the tractive power. The greater portion of the weight is then made to rest on these, so as to obtain as much hold on the rails as possible. In many foreign engines the number of tubes is very largely increased, and the whole machine is made very cumbrous and unsightly, the boiler being in several instances made to overhang the wheels.

Nearly all lines are now laid of a uniform gauge of 4 feet 8½ inches, that being the width between the rails, and this, of course, limits the dimensions and powers of the engine materially. A wider gauge was laid down on some lines, but from the inconvenience caused by being unable to run over other companies' lines, and also from the greatly increased cost of the rolling stock, this broad gauge is now but little used. A few trains still run on it along the Great Western Railway, but a third line is laid down all along it for narrow-gauge trains, and these are most generally run.

On a few lines a much narrower gauge is used; the best known example of this is a short railway in North Wales, running down from some quarries at Festiniog to the sea-coast. This line is about fourteen miles in length, but its course along the mountain side is very circuitous; it has a gradient of about 1 in 120. The gauge on this is about three feet; and the railway thus constructed has been found to answer well, and is much more economical both in its first cost, and in working.

In some engines the front part, instead of being mounted on a single pair of wheels, is supported on a "bogie" or truck with two pairs. This is connected with the engine by a stout pin, which allows of a certain amount of play, and it is found that an engine thus mounted can travel along curves with much greater ease than the ordinary form. In other engines the bearings of some of the wheels are, with a similar object, so formed as to allow a certain amount of lateral play, which is found very beneficial.

Another important point is to have the wheels carefully mounted on springs, so as to prevent vibration as much as possible. This causes the engine to work much more regularly, and allows the wheels to have a better hold on the rails. Coiled or volute springs and india-rubber blocks are often used for this purpose in addition to the plate-springs shown in the figure.

Several of the wheels are usually fitted with brake-blocks, which may be forced upon them by means of a screw: these very speedily reduce the speed, and bring the engine to a stand.

It is found a very economical plan on extensive railways to make the engines resemble one another as much as possible, so that the various parts may in a great measure be interchangeable, as otherwise an engine may often be standing a long time idle, from some trifling injury. It is often found that a large amount of capital is thus locked up in engines undergoing repair.

We have now explained all the main details of the locomotive; in most other points it closely resembles the engines already described. We must now leave the student to follow out alone the whole details of any engine he may meet with. If after having carefully studied these papers, he can examine a large engine at work, or, failing this, can, when waiting at a railway station, stand by a locomotive and trace out the various parts we have explained, he will find that this practical study will fix firmly on his mind what he has learned, and will clear up any points upon which he may feel at a loss. Careful reading followed by personal observation is always the best plan of acquiring a thorough acquaintance with any subject.

TECHNICAL DRAWING.—XLIII.

DRAWING FOR STONEMASONS.

The subjects of the present lesson are the plan (Fig. 395) and the sectional elevation (Fig. 396) of a cornice and blocking course.

The *cornice* is the projecting course at the top of a building, finished by the blocking course. Cornices are but ramified copings, and are or may be subjected to the same general laws. Care must be taken, however, in arranging them, that their centre of gravity be not brought too far forward in the anxiety to project them sufficiently, lest they act injuriously on the wall by pressing unequally, and their own seat be also endangered. A blocking course is either a very thick spring projecting over, or flush with, the face of the lower part of the wall, to cover a set-off, or it is a range of stone over a crowning cornice, to bring the centre of gravity more within the wall than it would otherwise be. In the former case it is treated exactly as a string, excepting that if it be flush below, there will, of course, not be any throating; and in the latter it has a horizontal bed, parallel vertical sides, and a weathered back or upper surface. With these explanations it is hoped the student will comprehend the drawing, and will be able to execute it satisfactorily.

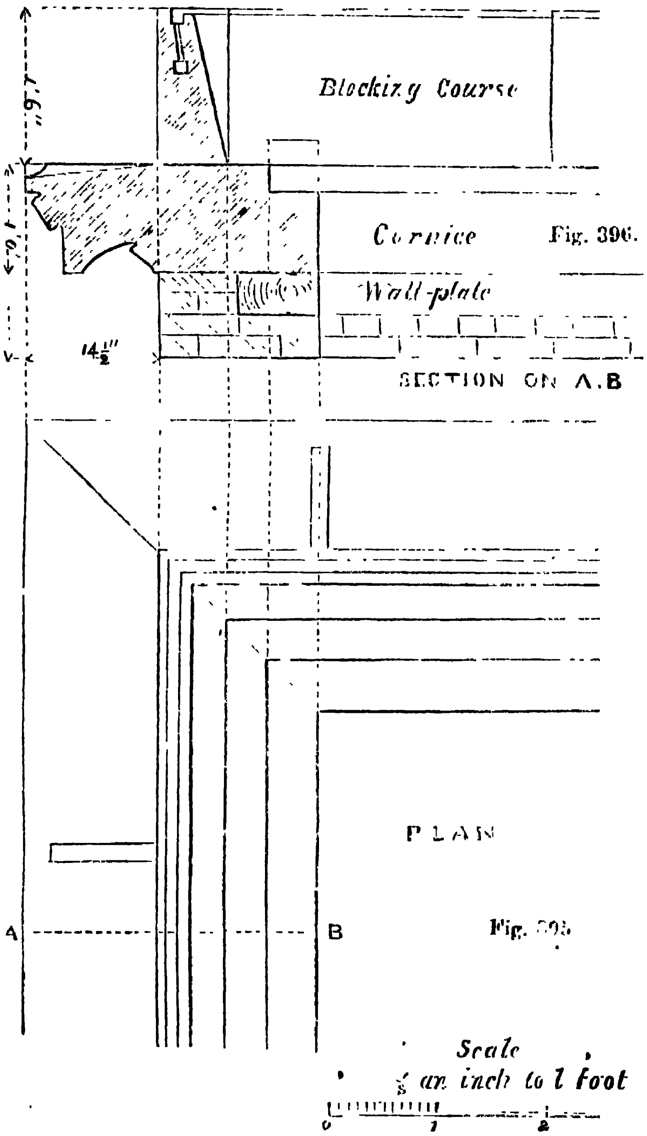

Fig. 396.

Fig. 395.

PROJECTION—SECTIONS OF CUBES.

There is no branch of projection which is of more importance to stonemasons than that which treats of sections, and it is, therefore, here proposed to describe and illustrate a few of the forms which are generated by means of making different cuttings of the cube.

It has already been shown in the lessons in "Projection," that if a cube be so placed as to rest on one side of its solid angles, whilst the base is so raised that one of its diagonals assumes the position of a horizontal line, the diagonal of the solid which connects the front angle of the top with the opposite angle of the bottom, will also be a horizontal line, as shown at A B (Fig. 397); and that if the cube be then rotated on the angle C, the front view will be a regular hexagon, shown in Fig. 398. The system of projection on the inclined plane has been fully worked out in previous lessons.

Having proceeded thus far, draw the line D C (Fig. 397), and let us endeavour to find the true form of the section of the cube which would be thus produced.

It will be evident that the point D not only represents the one angle of the cube, but that it hides one beyond it, which becomes visible when the cube is rotated on the angle C, as shown at *d* and *d'* in the front elevation (Fig. 398). Now, if *d* and *d'* be joined to *c*, the true section on D *c* will be found to be an equilateral triangle.

Returning now to Fig. 397, draw the perpendicular line passing through the middle, I, of the line D H, and cutting the edge D G in E and C H in F.

Having now drawn the plan and projection of the cube shown in Fig. 399, draw a horizontal line from I, cutting the projection (Fig. 399) in *i* and *i'*; also draw horizontal lines from E, cutting the projection in *e e'*, and from F, cutting the projection in *f f'*.

Join *e e'*, *e' i'*, *i' f'*, *f' f*, *f i*, and *i e*, and it will be seen that this section is a regular hexagon. Now draw horizontal lines from the angles of the plan of Fig. 399, and perpendiculars from the angles of Fig. 397, thus obtaining Fig. 400, the plan of the cube when raised on the solid angle. Then draw perpendiculars from I, cutting the plan in *i'' i'''*; join *a' i'' b'* and *i'''*, and the lozenge thus formed will be the horizontal section on the straight line A B.

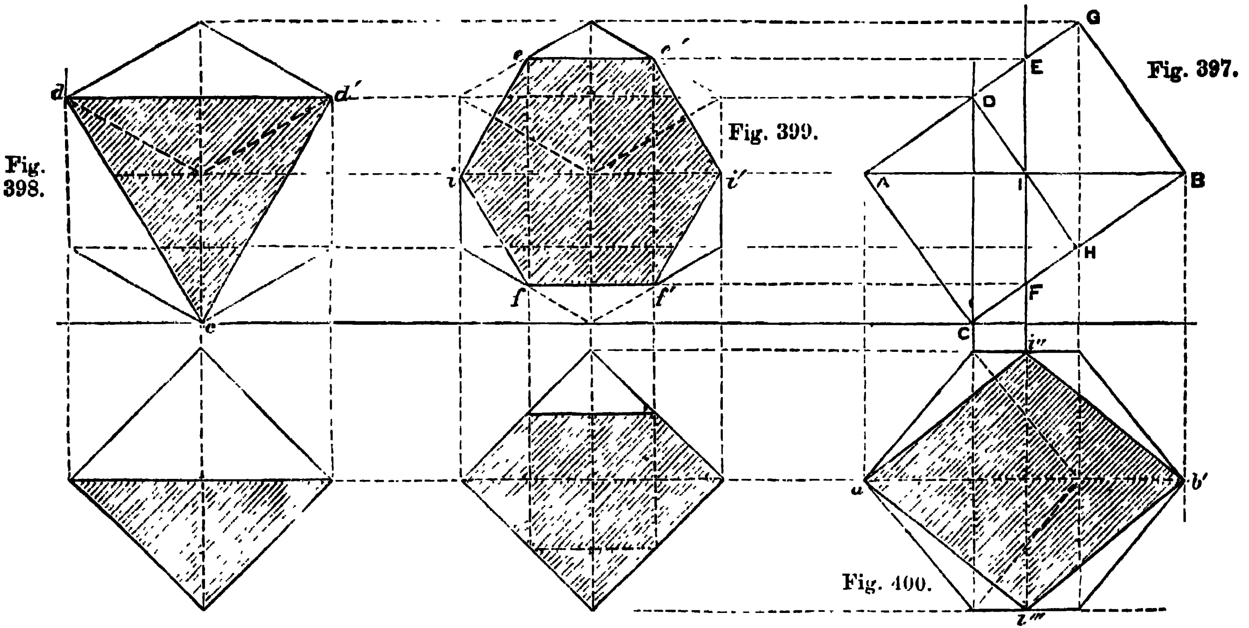

Fig. 398.

Fig. 399.

Fig. 397.

Fig. 400.

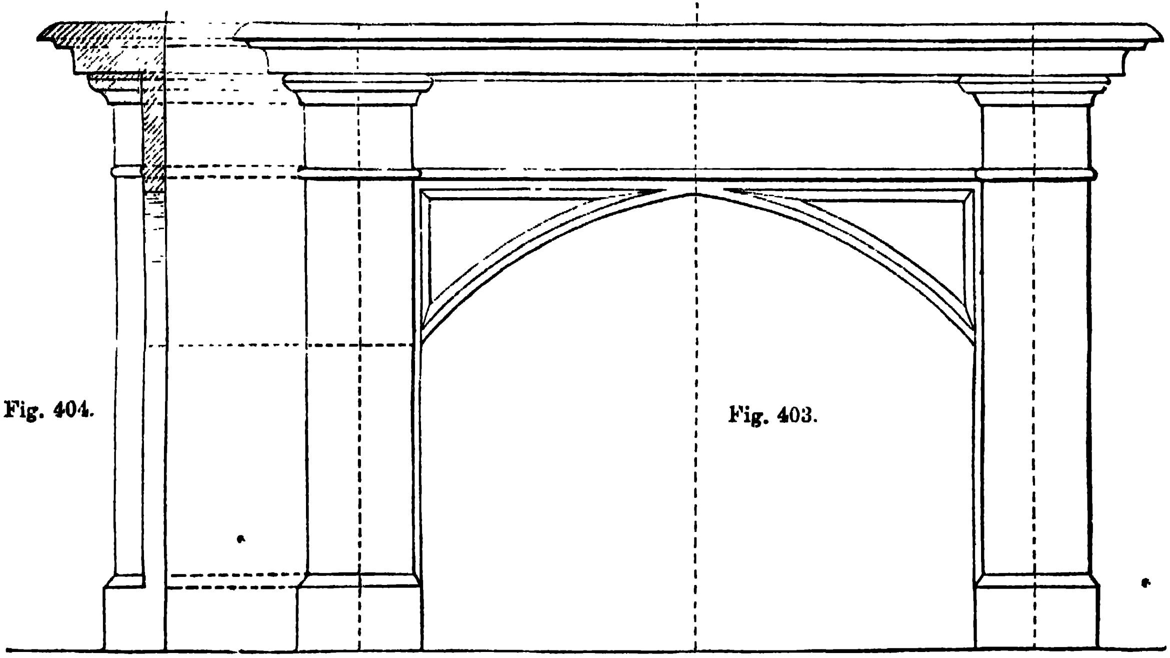

Fig. 404.

Fig. 403.

LINEAR DRAWING BY MEANS OF INSTRUMENTS (*continued*).

Fig. 401 in the next page is the elevation of a window, with mouldings and cornice; and Fig. 402 is a section of the cornice and traverse on the line A B.

This example is very simple in its character, but will test the student's power in accurate drawing, since all the lines of the different members must be truly parallel to each other, and the joints at the angles must be carefully and neatly made.

In commencing this subject, draw the central perpendicular, and set off on it the three parts *a b*, *b c*, and *c d*, representing the three parts—viz., the architrave, frieze, and cornice—into which an entablature is divided.

Next draw the complete rectangle *e f g h*, and set off within it the width *i e* and *h j* corresponding with *b a*.

Lines drawn at 45°, to unite the inner and outer lines of the jamb with those of the lintel, will aid, not only at the present stage, but will be found very serviceable in drawing the mouldings into which the space *a b* is subsequently to be divided.

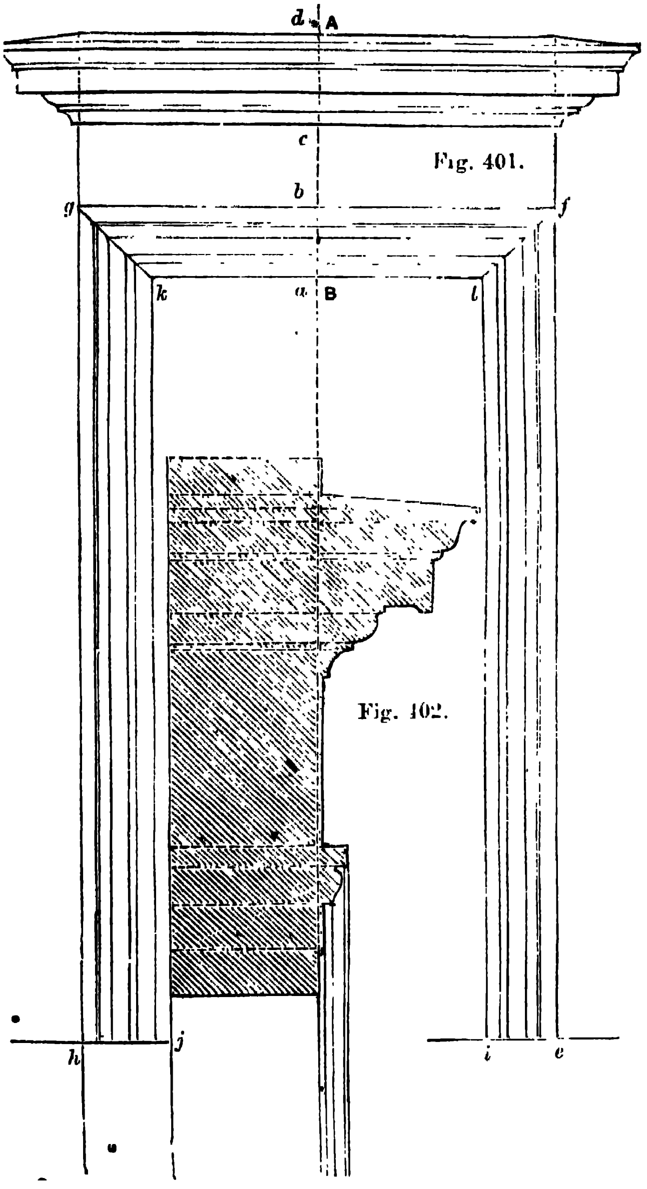

Fig. 401.

Fig. 402.

To draw these separate members, set off the divisions on the central perpendicular between *a* and *b*, and draw horizontal lines through the points of division.

Set off the same points between *e* and *i* and *h* and *j*, and draw perpendiculars through them; these should, if the work be correctly done, meet the horizontals on the lines *f l* and *g k*.

The cornice is now to be completed by drawing the true forms of the ends of the various mouldings of which it is composed. These will be better understood on referring to the enlarged section (Fig. 402), which it is expected the student will, after his previous practice in drawing mouldings, be able to follow without any difficulty.

Fig. 403 is a simple design for a Gothic chimney-piece. A chimney-piece is an ornamental addition to one side of a room, surrounding, and, with the mantel-shelf surmounting, the fire-place. We say *ornamental* addition, because it is not really necessary, since the aperture containing the fire could be simply walled round, without any architectural features to decorate it. This being so, the chimney-piece should never be too large, but should be in keeping with the size and general features of the room—a consideration often too much neglected.

Chimneys are of comparatively modern introduction, and therefore we have no precedents in ancient architecture in order to direct our taste in the decoration of this construction, whilst on the Continent the heating arrangements differ entirely from ours; and thus it has been mainly in England that chimney-pieces have become special features in interior architecture, the good taste in this department having been introduced by Inigo Jones. Since his time, however, the manufacture of mantel-pieces has become a regular branch of the mason's trade, and, owing to the introduction of machinery in working marble, they are supplied at a much cheaper rate than formerly.

The method of drawing this example is precisely similar to that already shown in the last plate. A central perpendicular should be drawn in each pilaster, and the profile of the mouldings must be set off from it. The arch is of the class termed "segmental"—that is, it is formed of two segments of circles, the centres of which are below the springing.

Fig. 404 is a section through the crown of the arch; the method of projecting this will be easily understood from the example.

CIVIL ENGINEERING.—X.

BY E. G. BARTHOLOMEW. C.E., M.S.E.

DOCKS (*continued*).

THE necessity of being able to examine the exterior of a ship from the keel to the bulwarks, for the purpose of cleaning, painting, or repairing, is self-evident, and although it may be possible under emergencies to contrive some method of excluding the water for this purpose from a limited portion of the hull, even whilst the vessel is afloat, yet some means must of necessity be resorted to for placing the entire ship at times in the same dry state she was in previous to launching her.

The graving-dock supplies this means, and whatever method be adopted for obtaining this end may be regarded as a *graving* or *dry* dock. There are two totally distinct methods of removing the water from the exterior of a ship. The oldest, and the most obvious, is to drag the vessel out of the water. This plan, adopted in very early periods by the Greeks, who simply hauled their ships upon the sand, and then raised a bank of earth around them to exclude all access of the water, might have proved sufficiently available for the small ships built in earlier times; but as the size and weight of vessels became greater, the mechanical contrivances known in those days would appear to have failed in accomplishing the result, and the next obvious method was then resorted to—namely, that of excavating the land, and floating the ship into the excavation at high water. This plan in its rudest form is adopted at Hong-Kong; a mere excavation being made in the shore, into which the vessel is floated at high water, a bank of mud protected by fascine work being hastily raised across the entrance at low water; the water which yet remains, or finds an entrance by percolation, being kept under by pumping.

We have here, then, the two methods of dry-docking a vessel. the first, that of raising the vessel out of the water—the plan resorted to in the earliest times, but which failed in the case of large ships until modern engineering skill has enabled us to adopt the same method in the case of the largest vessels; the second method of dry-docking a vessel, and the method the most usually resorted to, that of floating the ship into an artificial excavation at high water, and closing the entrance, when the water can be removed either by the fall of the tide through sluices, or by pumping out. Of course, where the fall of the tide is limited, or, as in the greater part of the Mediterranean, fails altogether, the entire process of removing the water must be by pumping.

The construction of an excavated graving-dock differs essentially from that of an ordinary or floating-dock. They may, in fact, be regarded as the direct converse of each other. In the floating-dock the object is to keep the water *within* the excavation; in the dry-dock every effort must be made to keep the water *out* of the dock.

The sides of a dry-dock always slope considerably towards the bottom. The depth to which the excavation is carried must depend upon the draught of the vessel intended to enter it, and, like the wet-dock, must be as great over the entrance-sill as the channel of approach. Timber is sometimes employed for lining the sides of small graving-docks, but masonry is preferable, and the floor should in all cases be lined with brick, stone, or concrete. To facilitate access to the dock the sides are constructed with steps, or "altars," which at the same time serve as convenient resting-places to the shores or struts which support the vessel, and retain her in a vertical position after the water is withdrawn. The entrance is closed either by gates or a floating pontoon. If by gates, they are made to open outwards, and conversely to the arrangement of the wet-dock, the union of the shutting-posts is outside the straight line lying between the heel-posts. After a ship has entered the dry-dock she is brought into the centre by hawsers, and as the water is withdrawn and she settles down upon her keel, a proper system of blocks, wedges, and struts must be arranged in order that her vertical weight shall be distributed uniformly over her keel, and her position retained there by horizontal shores. The details of these arrangements need not be considered here, as they belong more properly to naval architecture.

The form of a graving-dock is that of an elongated parallelogram with either rounded corners or curved extremities. In Fig. 18 we show a section of a graving-dock, as seen from either extremity, and in Fig. 19 a plan. The same letters refer to both figures; A, A representing the broad altar usually half-way up; F, F, the floor; C, the entrance, closed either by gates or a caisson.

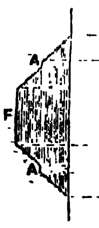

Fig. 18.

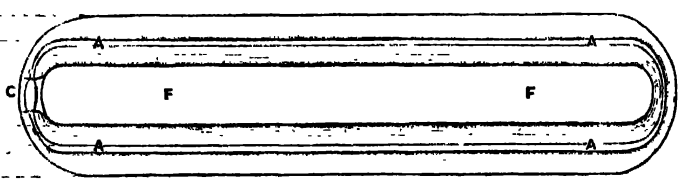

Fig. 19.

At Boston, U.S., are some fine graving-docks of the kind we have been speaking of. They are 341 feet long, and 80 feet broad at the ground-level. The depth of the dock is 30 feet from the level of the water at high tide; but as the fall of the tide is only 13 feet, 17 feet of water must be removed by pumping. They are lined with granite, and their cost was £150,000 each. The large dry-dock at Portsmouth has the following dimensions:—

	ft.	in
Length of floor	400	0
,, of coping	126	0
Width at floor	35	0
,, at broad altar	75	0
,, at coping	99	0
Depth from coping to floor . . .	33	10
,, at high-water springs . . .	28	4

The lining is of granite from the floor to the level of the broad altar, 18 feet; the remainder and the floor being finished with Portland stone, bricks, and concrete.

The large dry-dock erected for the United States Government at New York may be instanced as one in which a great amount of engineering skill was exhibited, owing to the very formidable difficulties which had to be overcome; its history is therefore most instructive.

The ground selected for the position of this dock proved to be of an exceedingly treacherous and unsuitable character. The superstratum, for a depth of ten feet, is formed chiefly of decomposed vegetation, the growth of centuries, the annual decadence of the primeval forests which once covered the country. Below the vegetable matter lies an almost impalpable quicksand containing a large proportion of mica. The peculiar characteristic of this sand is its firm, unyielding nature when dry, and its almost fluid state when saturated with water, in which condition it is moved by the slightest current of water passing over it. Trial borings were made to a depth of 80 feet, and unfortunately these borings hit upon a mixture of clay with sand, and although they failed to show the existence of rock, yet the presence of the clay led the engineer to decide upon the position eventually adopted. The discovery of clay was truly a misfortune, inasmuch as it was subsequently discovered that the clay was confined to a very small portion of the area required for the dock, the remainder being nothing but quicksand of the nature described. The presence of sand led to the necessity of constructing an immense coffer-dam which should entirely surround the future dock, in order to resist the pressure of the treacherous soil, and keep back the water which percolated through it, since the foundation of the superstructure had to be laid 37 feet below mean-tide. The original dam was commenced in 1842, and the piles used in the first instance were of yellow pine, 15 inches square, and from 35 to 40 feet long, secured at the top and at the level of low water by horizontal wailings of oak 12 inches square, firmly bolted and tied once in every 10 feet with iron tie-bolts 2 inches in diameter. A change occurred at this period in the superintending engineer, and the new superintendent deemed it desirable to give up the use of yellow pine, in consequence of the hardness of the bottom soil splitting and shattering the wood under the blows of the pile-driver. Green timber was accordingly employed with success.

The dam was completed according to the original plan in 1846, being 470 feet long, and from 60 to 100 feet wide, with wings 175 feet long and from 15 to 30 feet wide. The framework stood well the removal of about 30,000 cubic yards of soil, but when only 6 feet of water had been pumped out, it became evident that the dam would yield to the external pressure. The result was that nearly the entire length of the north-west wing was forced in at the top, and very shortly afterwards a part of the front of the dam was forced outwards, breaking some of the iron tie-bolts; and as the water continued to be withdrawn, nearly every part of the dam yielded more or less. This obvious weakness in the original construction resulted in the necessity of driving an additional row of piles inside the former row, and entirely round the dam, the piles penetrating to a greater depth than the former ones. With this additional strength, however, the dam yielded at one point, piles settling down vertically 3 feet which when drawn were found to measure from 33 to 37 feet in length. Water had evidently penetrated beneath them; consequently fresh piles 50 feet long were driven along the face of the dam, whilst another row of equal length was driven parallel to these and at a distance of 30 feet from them, for a length of 200 feet opposite the portion which had yielded. A month or two after this a third breach occurred at the north-west angle of the dam, and was first indicated by a sudden increase in the flow of water in one of the bottom springs, and also by its change of character from fresh to salt; the change alternating several times within a few minutes; and in less than an hour the volume of this spring had increased to five times its former amount, bringing up in its waters immense quantities of the black mud which overlays the quicksands in the bottom of the bay. Some of the piles shortly settled down vertically from 5 to 6 feet, and in this instance again the evident cause of the breach was the insufficient length of the piles. Subsequently fresh piles of from 50 to 62 feet long were employed; yet so unstable was the material upon which the dam rested, that although the piles penetrated it from 15 to 25 feet below the foundations of the dock, it still continued at times to yield to the pressure of water and soil, and was only sustained by the closest watchfulness.

As the excavation proceeded, and as consequently the support afforded internally by the soil was withdrawn, it was found necessary to attach chain-cables of iron two inches in diameter to the dam, and secure them to mooring blocks on the shore; these cables were, however, frequently broken, no less than six being fractured in one night upon one occasion. Gradually, as the work progressed, rows of foundation-piling were driven in front of the main piles, and at a few feet distant, buttresses of earth being left behind them, and against these struts of timber were planted, their heads pressing against the dam. The masonry on the foundation was laid in sections, and braces were likewise extended from it to the dam. The thrust upon these braces was so enormous, that on one occasion it had the effect of moving bodily a mass of masonry exceeding 250 tons in weight.

The coffer-dam was composed of a number of piles reaching a total of 3,504, their average length being 39 feet, and having an average section of 15 × 15 inches; the entire cost of the dam, including repairs to breaches, being £51,243 11s. 9d.

The *excavation* for the dock covered an area of 2 acres at top, and rather more than 1 acre at bottom, and extended to a depth of 42 feet; being 37 feet below mean high-water, and required the removal of 112,000 cubic yards of earth; the semi-fluid nature of the soil rendering its removal both difficult and expensive. The cost of excavation alone was £29,463 12s. 11d.

The obstacles opposed to the progress of the work from the number and magnitude of the fresh-water springs found at the bottom of the excavation were immense. They were wholly unconnected with the tides, as was evidenced by their difference of temperature and perfect freshness, and proved that their origin came from a far higher level, by their pressure. The water they discharged contained a large proportion of exceedingly fine sand, there being from 17 to 27 ounces of sand in from 33 to 38 gallons of water. The largest of the springs discharged 10 gallons of water per minute. The sand was of the same character as that in which the piles were driven, and the danger of its removal arose from the gradual undermining of the whole coffer-dam. It was utterly impossible to check the flow of the water with safety, as its pressure under accumulation was found sufficient to raise the foundation, however heavily loaded. It was therefore necessary to provide for its flow, and at the same time to check the escape of the sand. So great was the pressure of the pent-up water that in one case it burst up through a bed of concrete 2 feet thick; and this outburst being checked, it in a few days burst up through another bed 14 feet distant. The ultimate course adopted was as follows:—An area of 1,000 square feet around the troublesome spring was laid with plank; upon this was laid a floor of brick in dry cement, and upon that another layer of brick with Roman cement. The space was next filled with concrete, and the foundations completed over all with the utmost despatch, vent-holes being left through the floor and foundations. By this means the exit of the spring was forced up to a level 10 feet higher, and it was then found to run free from sand.

During some severe weather in 1848, two of the springs were closed by freezing, and as a consequence forced up 1,200 feet of the foundation, including the first course of stone, which was from 12 to 15 inches thick. None of the springs were closed until the inverts had been laid and the cement well set, and when closed they exerted an upward pressure so great as to force the water through the joints of the masonry, without, however, disturbing the stone-work. A 25 horse-power engine was kept in constant work to keep under the in-flow of water, the cost alone of temporary drainage being £14,142 10s. 10d.

The entire superstructure of masonry rests upon bearing piles from 25 to 40 feet long, and averaging 14 inches in diameter at the head. They consist principally of round spruce. The sheet-piles are of yellow-pine plank 5 inches thick, and averaging 15¼ feet long. The character of the soil was such that it was deemed expedient to drive as many piles as could be forced into the earth, and they were for the most part driven up to the point of absolute resistance, and whenever a weight of 2,000 pounds falling 35 feet ceased to drive a pile more than 3 inches at a single blow, another and a larger pile was driven alongside it. Each pile while being driven was protected at the head by a band of iron 1 inch thick and 3 inches deep, made of the toughest iron that could be produced. The total number of round piles under the foundation is 6,539, and of sheet piles 1,744. The greater number of these piles were driven by hammers or "monkeys" weighing from 2,000 to 4,500 pounds each, falling from 30 to 40 feet, and the average number of blows given with the smaller hammer was 151, and with the larger hammer 50; an instructive fact, showing the advantage resulting from the employment of a heavy hammer for pile-driving, since a hammer weighing only 2·25 times another hammer, performed fully three times the work. A small portion of the piles—541—were driven with a Nasmyth's steam pile-driver, but its frequent derangement prevented its relative value being fairly tested.

The foundation of the dock was laid on the levelled heads of the bearing-piles in the following manner:—Concrete masonry 2 feet deep was laid between the bearers and levelled with their heads, which were then capped with yellow pine of a scantling 12 × 14 inches laid transversely with the axis of the dock, and fastened to each pile with trenails. Concrete was again laid between these timbers and raised to a level with them, and a flooring of 2-inch yellow-pine plank laid upon and spiked to them. Another and a similar course of timber was laid upon this floor, breaking joint with the lower planks and trenailed to them; the intervals were again filled with concrete, and another floor of plank laid over all. The concrete employed was composed of 1 part of hydraulic cement carefully tested; 2 parts of coarse, clean sand; 3½ parts of broken stone; and 2¼ parts of beach pebbles; the cement and sand being first mixed into a mortar, then the broken stone added and well mixed, and lastly the pebbles. The cost of the foundation to the point indicated was £32,115 9s. 10d.

The apron of the dock extends for a distance of 45 feet into the channel of the bay, the foundation of the apron being strengthened by additional piles whose heads were covered with bevel-hewn timber secured by trenails, the space around and between the piles being filled with concrete to a depth of 2 feet; whilst dovetailed stone blocks are placed between the timber to prevent their floating, the whole being covered with 3-inch plank.

In the foundation and superstructure of this dock 80,000 tons of stone were employed. The masonry foundations are 400 feet long and 120 feet broad. The dock is capable of being used either in whole or in part, there being gates placed intermediately between the extremity and the entrance at a distance of 52 feet from the latter; the entrance itself is closed by a caisson. The main chamber is 286 feet long and 30 feet broad at the bottom, and 307 feet long and 98 feet broad at the level of the coping; and the entire length available at mean high-water is 350 feet. The least width is at the hollow quoins of the gates, where the dock narrows to 68 feet, and the least depth is over the mitre-sill, where the water is 26 feet deep at high-water. The vertical height of the wall is 36 feet. The flooring of the dock is an inverted arch formed of stone from 4 to 6 feet deep, each stone being very large and heavy, the smallest weighing over 3,000 pounds, and many over 15,000 pounds. The mitre-sills are of granite blocks of immense size, the key-stone before being cut having had an estimated weight of 50 tons; after being dressed it weighed 43,300 pounds.

The cost of the masonry, exclusive of cutting the stone, was £89,515 15s. 8d., and the cost of cutting was £50,009 19s. 8d.

The gates are of iron, and with the machinery for working them weigh 187 tons 8 cwt. Their entire cost, including machinery, was £13,989 3s. 4d. They are curved on the interior face to a radius of 74 feet 9 inches, which of course corresponds with the curve of the mitre-sill, and 76 feet 8 inches on the exterior face. They can be closed in ten minutes by four men to each leaf.

The caisson is an iron vessel 50 feet long at the keel, and 68 feet 8 inches at the top. The breadth of beam is 16 feet at the mid-ship section, and 7 feet at the keel. The keel and stems are built up of plates of ¾-inch iron to a combined width of 2 feet, and have a projection of 9 inches. The frame is composed of vertical ribs of iron, 31 on each side, bent to the form of the vessel, and covered with boiler plate stiffened at the contact with the ribs with angle iron. The thickness of the plates varies, being of ⅝-inch iron at the bottom, and diminishing gradually by ⅛ to ¼-inch at the top; the whole being secured to the ribs by rivets. The interior horizontal layers or decks are supported by hollow cast-iron columns, 6 inches in diameter and 4 inches bore, through which are passed 3-inch wrought-iron rods, secured to the keel-plate and main-deck by keys. The weight of the caisson is 217 tons 9 cwt. 73 pounds, and carries a weight of 105 tons 11 cwt. 63 pounds as ballast. Its cost was £18,544 15s. 4d. The pumps for removing the water from the dock are capable of emptying it in 2⅙ hours, its capacity being 610,000 cubic feet. The steam-cylinder actuating the pumps is 50 inches diameter, and 12 feet stroke. There are two pumps, each barrel being 63 inches diameter, and 8 feet stroke.

The removal of the coffer-dam after the construction of the dock was completed was a work of considerable difficulty. The first pile drawn from the outer row required a force of 630 tons to start it out of the earth. No application of chain-cables and levers were of any use, but they were finally extracted by a "Dick's Anti friction Press" worked by four men.

The dock occupied from first to last a period of ten years in construction, and has involved a total cost of £449,357.

PRINCIPLES OF DESIGN.—XX.

BY CHRISTOPHER DRESSER, PH.D., F.L.S., ETC.

CARPETS, AND WOVEN FABRICS GENERALLY.

Before we leave the consideration of carpets we will state in axiomatic form the conditions which govern the application of ornament to them, as reference can more easily be made to short concise sentences than to more extended remarks.

1st. Carpet patterns may with advantage have a geometrical formation, for this gives to the mind an idea of order or arrangement.

2nd. When the pattern has not a geometrical basis, a general evenness of surface should be preserved.

3rd. Carpets are better not formed into "panels," as though they were works of wood or stone, but should have a general "all over" effect, without any great accentuation of particular parts. The Indian and Persian carpets meet this requirement.

4th. While a carpet should present a general appearance of evenness, parts may yet be slightly "pronounced" or emphasised, so as to give to the mind the idea of centres from which the pattern radiates.

5th. A carpet should, in some respects, resemble a bank richly covered with flowers; thus, when seen from a distance the effect should be that of a general "bloom" of colour. When viewed from a nearer point it should present certain features of somewhat special interest; and when looked at closely new beauties should make their appearance.

6th. As a floor is a flat surface, no ornamental covering placed on it should make it appear otherwise.

7th. A carpet, having to serve as a background to furniture, should be of a somewhat neutral character.

8th. Every carpet, however small, should have a border, which is as necessary to it as a frame is to a picture.

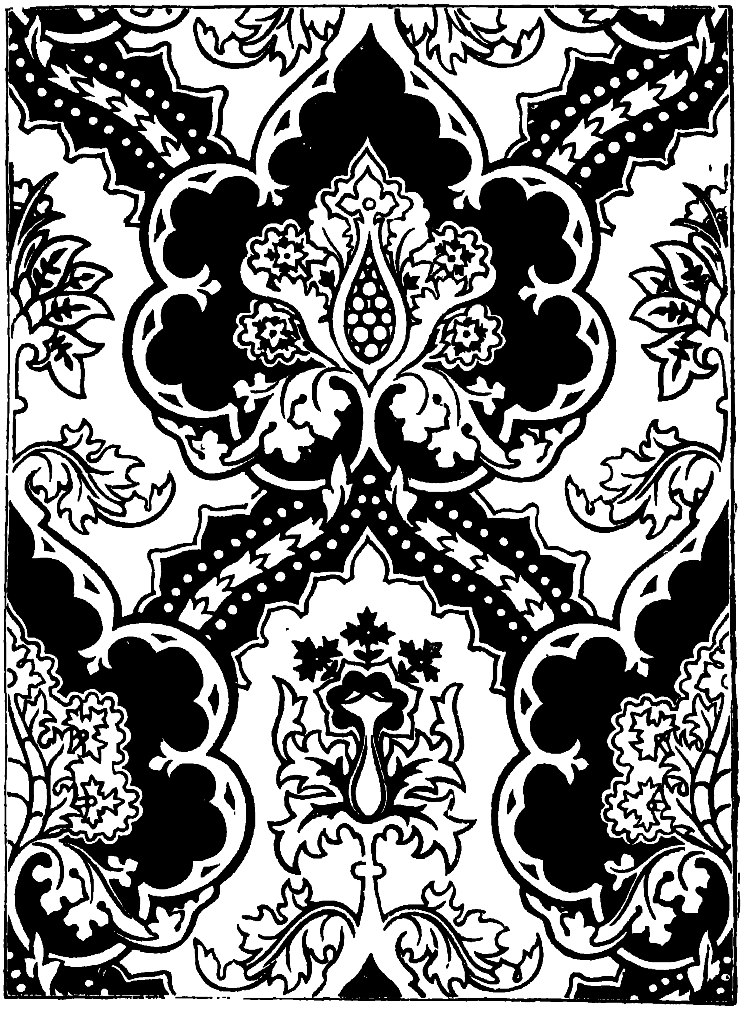

Fig. 69.

Having thus summarised the principles that govern the application of ornament to carpets, we may proceed to notice the conditions governing the decoration of other woven fabrics.

The first thing to be considered is the nature of the cloth on which the pattern is to be worked—whether it is of open or close texture. Fabrics of an open character should bear upon them a larger pattern than those which are thicker or closer. The openness or closeness of the fabric will thus determine, to an extent, the nature of the ornament which is to be placed upon it. Muslins, being open in character, should have larger patterns than calicoes, which are closer in texture, or the pattern will be indistinct in the one case or coarse in the other.

But not only does texture influence the pattern when considered as to coarseness or fineness, but also the nature of the cloth as regards material. Thus silk will bear greater fulness of colour than muslins or calico-prints, owing to the fact that the lustre of the material, by reflecting light to the eye of the observer, destroys a certain portion of the intensity of the effect of colour which a less reflective material would exhibit. Silk, as a material, also conveys to the mind an idea of costliness or worth, and wherever the material does so the pattern may be richer in colour than it should be in cheaper and commoner fabrics. If a pattern is in two tints of the same colour only, as in the case of those woven silks where the pattern is formed by the contrast of "tabby" and satin, it may be considerably larger than in those cases where it is rendered conspicuous by colours.

This latter remark will apply also to damask table linen, and to all similar materials, as well as to dress fabrics, and draperies such as window hangings; but of these we shall say a word shortly.

The closeness or openness of a fabric should, then, be considered when we design patterns for their enrichment, and so should the nature of the material, as this will influence its deadness or lustre. But there are also other considerations which must not be lost sight of. If the pattern is to be wrought by printing, then one class of conditions must be complied with; if by weaving, then another class of requirements call for consideration.

The requirements of manufacture are much more numerous than might be supposed, and are in some cases very restrictive. The size of the repeat, the manner in which colour can be applied, the character of surface attainable, and many other considerations have to be carefully complied with before a pattern can appear as a manufactured article.

The chief fault of patterns, as applied to fabrics generally, is their want of simplicity, want of simple structure, want of simple treatment, want of simplicity of effect; and together with this we generally find largeness and coarseness of parts.

These errors arise largely out of a want of consideration of the capabilities of the material. What can be done with this or that particular fabric, is a question that we should carefully ask ourselves before we think of preparing a design. Have we colour at our disposal, or texture merely? and if colour, can it be employed freely or only sparingly? and can any colours be placed in juxtaposition or only certain tints? These are questions of great importance, and they should be asked and carefully considered before the first step is taken towards the formation of a pattern. Having ascertained what can be done with the material at command, let us ever remember that we should always endeavour to so employ the capabilities of a material as to conceal its weakness and emphasise its more desirable effects. If this consideration were always given by designers to the power which the material has of yielding effects, we should see, in very many instances, effects strangely different from those which we often encounter; and this remark applies to no class of fabrics more fully than to damask table-linen and coloured damask window-hangings.

No satisfactory effect can be got in light and shade upon any woven or printed fabric; besides, to attempt such a mode of treatment is absurd. Light and shade belong only to pictorial art. The ornamentist when enriching a fabric deals only with a surface, and has no thought of placing pictures thereon; he has simply to enrich or beautify a surface which without his art would be plain and unornamental. A picture will never bear repetition. Who ever heard of a man having two copies of one picture in a room? Yet how much more absurd is it to repeat a little picture—perhaps a pictorially rendered flower—a hundred times over one surface! Besides this, a surface must always be treated, for decorative purposes, as a surface, and not in a manner calculated to deceive by giving apparent relief, or thickness, to that which is essentially without thickness. Take a common damask table-cover. This is by custom always white, although it would be better if of a deep cream colour, or buff; and the pattern which it bears results from a change of surface only (why a margin of "ingrain" colour is not added, I could never see); yet in nine cases out of ten the pattern which is presented by such a fabric is a miserable shaded attempt at a pictorial treatment, and is also a thorough failure.

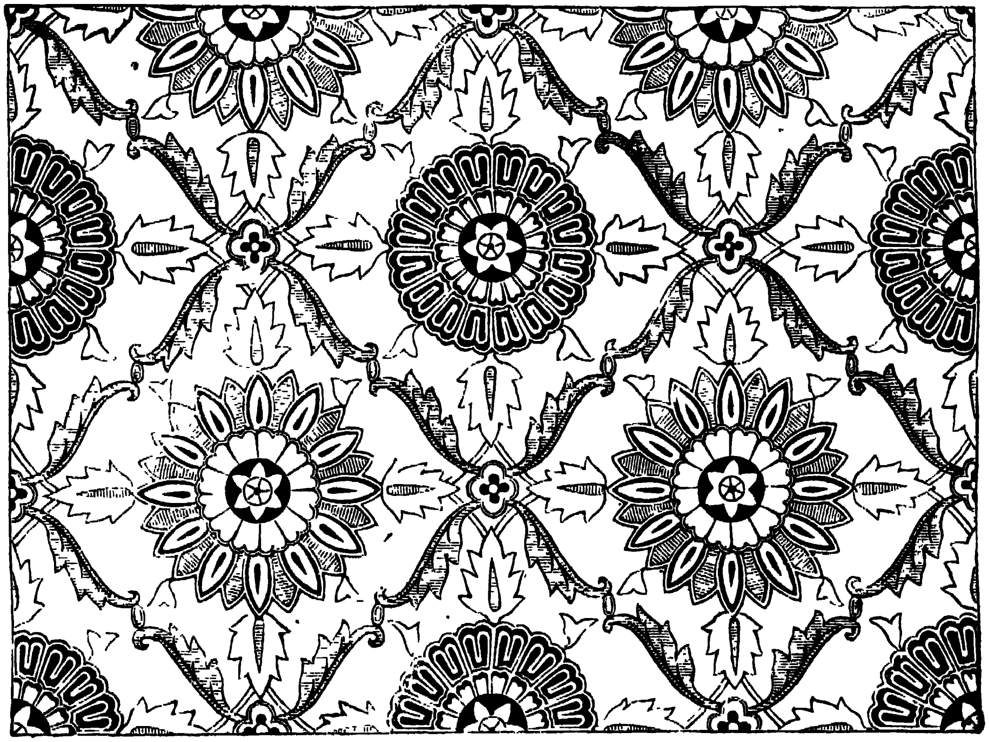

Fig. 70.

Simplicity of pattern naturally accords with a simple mode of production, and the means of producing pattern in damasks is certainly most simple. Yet that there is a natural harmony between simplicity of pattern and simple means of producing an art effect is obvious, for of all patterns that I have ever seen upon damask table-linen the simple spot, or dot, is the most satisfactory. If, combined with this spot, we have a border formed of a simple Greek "key-pattern," or of mere lines (a very usual border to good cloths), the effect is perfectly satisfying, and, as far as it goes, is highly to be commended.

It is curious that this spot is only sold in the better quality of table-linen (at least so they tell me in the City), and this shows that the wealthy, or, in other words, the educated, buy such patterns, as they prefer the true to the meretricious, while the false and showy devices which we see on the common cloths please only the common people of vulgar taste. I am not sure, however, that many persons, whose means are limited, would not buy spots and other simple, but correctly treated, patterns, if such were to be got in common qualities of damask; but when the pocket must govern the purchase, it is hard to say that the false is preferred to the true, if the true is not procurable with the means at command.

While I cannot withhold praise from this little spot, it must not be thought that I thereby give to it a high place as an art work. Little is here attempted, and that little is done well. But let us analyse this pattern. First, the spots are of one tint throughout, if I may thus express myself—a tint, shall we say, which is the reverse of that of the ground. It is not shaded so that it may appear as a ball or globe, and is not graduated in "colour" in any way (were it graduated or shaded, feebleness of effect must inevitably accrue), but is a simple, honest spot, treated as a surface ornament. Second. This spot is geometrically arranged, or, in other words, has an orderly arrangement.

If an attempt is made at rendering a pictorial, or light-and-shade effect in damask, an absurd failure can alone result, for depth of shade is not obtainable in the material; and, besides this, what appears as shade, when the cloth is seen from one point of view, appears as light if seen from another point of view. Nothing could be more absurd, then, than seeking to produce shaded effects with such means as are here at our disposal. But were the fabric capable of rendering such effects, it would still be wrong to employ them, as we deal only with the surface, and are seeking to enhance the value of, or beautify, a fabric, and not to cover it with pictures. In our simple spot-pattern we have those elements which may be extended into the richest and most artistic damask patterns. We have order—as indicated by the geometrical plan of the pattern—and an honest and simple expression, or application, of the capabilities of the material.

All table-covers should certainly have a border. Any object which is to be used as a whole looks unsatisfactory if it appears as though it were a part of a whole. If a cloth is without border it is impossible to avoid the impression that it is a part of a larger cloth, and in every respect the general effect is decidedly unsatisfactory.

I introduce into this article two illustrations of woven fabrics. The first is that of Austrian cloth of gold (Fig. 69), the second of Indian embroidery on cotton (Fig. 70), but of these I shall speak in my next paper on this subject. I insert them in this article with the view of leaving room in my next chapter for some additional illustrations of woven fabrics which will aid us in our studies.

BIOGRAPHICAL SKETCHES OF EMINENT INVENTORS AND MANUFACTURERS.

XVIII.—JAMES FERGUSON, F.R.S.

BY JAMES GRANT.

JAMES FERGUSON, an eminent and self-taught mechanist and philosopher, inventor of the astronomical rotula, of a universal dialling cylinder, etc., was born in 1710, in the little village of Keith, in Banffshire, in the north of Scotland. His parents were very poor, but very religious and honest; as he states himself, "they lived in good repute with all who knew them, and died with good characters." His father was a mere cottar, and supported a large family by his daily labour, and the profits that arose from a few acres of land which he rented. Thus he could afford to bestow but little upon the education of his children, yet they were not neglected, for in his leisure hours he taught them all to write and read, and it was while he was teaching his eldest boy the Scottish catechism that James, the younger, learned to read; after he could do so perfectly, his father sent him to the grammar-school at Keith for three months, and that was all the education he ever received at a seminary.

His taste for mechanics arose from a very simple accident. When eight years of age, a part of the thatched cottage in which the family dwelt being decayed, his father frugally set about repairing it with his own hands. To his great astonishment, the child saw him lift up the whole roof as if it had been a small weight; and this he attributed to a degree of strength which excited his terror as well as wonder; but a little observation soon enabled him to perceive that his father applied his hands, not to the roof itself, but to the end of a lever. Little James therefore proceeded to amuse himself by making levers—bars he called them—and, by applying them in different ways, he discovered that the power gained by the bar was just in proportion to the lengths of the different parts of the bar on each side of the prop.

Thinking it a pity that by means of this bar a weight could be raised but a very little way, he imagined that by pulling round a wheel the weight might be raised to any height, by tying to it a rope, and winding the latter round the axle, and that the power gained thus must be exactly as great as the wheel was broader than the axle was thick. He found it to be just so, by hanging one weight to a rope put round the wheel, and another to the rope that was coiled round the axle; so that in these two machines it appeared very plain that their advantage was as great as the space gone through by the working power exceeded the space gone through by the weight. By means of a turning-lathe which his father possessed, and penknife, he contrived to make wheels and other things necessary for his machines, or models, illustrative of this power.

Imagining that it was the first idea of the kind that had ever been formed, the boy wrote a short account of his invention, and made diagrams of it with pen and ink; but on showing them to some one, he was informed, to his mortification, that such appliances were well known already, and his friend gave him a work on engineering, in which they were fully treated of and described. As his father could no longer afford to maintain him in what seemed idle pursuits, and the boy was too weak and young for hard work, he became what is termed "a herd laddie," and was hired by a neighbouring farmer to keep his sheep. In this humble occupation his earlier years were passed, and amid the pastoral solitude of the Banffshire glens, and by the shore of the Moray Firth, he learned to study the stars when lying amid his sheep by night; and all day long he amused himself by making models of mills, and spinning-wheels, and other mechanical contrivances, even to constructing for his own use a celestial globe.

His employer having observed that often in the evenings, when farm work was over, he went out into the fields, and, with a blanket or plaid about him, lay down on his back, and stretched a string with small beads upon it at full arm's length between his eyes and the stars, sliding the beads to and fro till they hid certain stars, laughed at him as being guilty of folly. But when the shepherd explained that he did so in order to take their apparent distances from each other, and that then, by laying the thread upon paper, he marked the position of the stars thereon by the beads, the farmer, who was a kind and indulgent man, encouraged him to go on, and actually did Ferguson's outdoor work at times, that he might in the day-time make fair copies of what he had done in the night. The Rev. John Gilchrist, minister of Keith, who had known him from childhood, on seeing what Ferguson called his "star-papers," kindly supplied him with some maps, ink and paper, a pair of compasses, and a ruler; but as copying the maps required more time than he could reasonably expect from his master, the latter, says Ferguson, in the preface to his "Select Mechanical Exercises," "often took the threshing-flail out of my hands and worked himself, while I sat by him in the barn, busy with my compasses, ruler, and pen." Having completed the copy of a particular map, he called at the manse, and while he was showing it to the minister, Thomas Grant, the Laird of Achoynaney, chanced to come in. The clergyman introduced the lad to him; and he was so pleased with his apparent genius that he offered Ferguson a room in his house, adding that if he came to live there the butler, another self-taught man, could give him a deal of instruction. This was too good an offer not to be accepted. He went to reside in the house at Achoynaney, and by the butler, whose name was Alexander Cantley, he was taught decimal arithmetic, algebra, and the elements of geometry. Nor were these the only parts of the butler's education, for it seems that he was a perfect mathematician, master of every musical instrument except the harp; that he knew Latin, Greek, French, and even some of the elements of surgery. On the butler obtaining a situation in the Earl of Fife's family, Ferguson declined to remain longer in Mr. Grant's house; he returned home, and proceeded to make for himself a globe, with a meridian ring and horizon; but all this skill and knowledge would not as yet give him bread, so he took service with a miller, with whom he remained a year, and was so starved for want of victuals, his master being a drunkard, that he was too often glad to get a little oatmeal mixed with cold water for food; so he returned once more, in a very weak state, to his father's thatched cottage.

There he constructed for his own use a watch, with wooden wheels and a whalebone spring, and this he enclosed in a wooden case, the size of a breakfast cup; but a clumsy neighbour to whom he was showing it let it fall on the clay floor, and it was broken to pieces. This discouraged him so much that he never attempted to make another; but his extraordinary ingenuity having now procured him the notice of Sir James Dunbar, of Durn, and several other county gentlemen, they endeavoured to assist him by their countenance and advice. He was employed to clean their clocks; and having learned drawing, he now began to take miniatures in Indian ink and make patterns for ladies' needlework, and the payments he received for these services enabled him to supply the wants of his father, who was now too frail to labour, and descending into the vale of years.

The gate pillars of Durn House were surmounted by two large globular stones; and on these he painted in oil-colours a terrestrial and celestial globe. "The poles of these painted globes stood towards the poles of the heavens; on each the twenty-four hours were placed around the equinoctial, so as to show the time of the day when the sun shone out by the boundary where the half of the globe at the time enlightened by the sun was parted from the other half in shade; the enlightened parts of the terrestrial globe answering to the like enlightened parts of the earth at all times. So that, whenever the sun shone on the globe, one might see to what places the sun was then rising, to what places it was setting, and all the places where it was then day or night, throughout the earth."

Half his nights were spent in gazing at the stars, and taking the places of the planets by his string and beads. By observing what constellations the ecliptic passed through in his map, and comparing these with the starry heavens, he became, in his enthusiasm, so impressed at times that he imagined he saw the ecliptic in the blue dome above, "like a broad circular road for the sun's apparent course; and fancied the paths of the planets to resemble the narrow ruts made by cart-wheels, sometimes on one side of a plain road and sometimes on the other, crossing the road at small angles, but never going far from either side of it."

Having married in May, 1739, and having, during a two years' residence in Edinburgh, studied anatomy, surgery, and physic with great intensity, he returned to his native village of Keith, with a stock of medicines and plaisters, etc., and endeavoured to establish himself as a doctor; but, to his mortification, he found that all his medical theories were of little use in practice. Thus he soon relinquished the attempt; and after endeavouring to make a livelihood by "picture-drawing" at Inverness for eight months, he began to think of astronomy again, and contrived and finished a scheme on paper for showing the motions and places of the sun and moon in the ecliptic on each day of the year perpetually, and, consequently, the days of all the new and full moons.

To this he wished to add a method for showing the eclipses of the sun and moon. By 1740 his astronomical rotula was complete; and having got the plates engraved, he published it, and this ingenious and brilliant invention sold very well until 1752, when a change in the style rendered it comparatively useless.

In Edinburgh he was befriended by Colin Maclaurin, professor of mathematics in the University. One day he requested the latter to show him his orrery, and was greatly delighted with the motions of the earth and moon in it. After long thought and calculation, Ferguson found that he could contrive the wheel-work requisite for turning the planets in such a machine, and giving them their progressive motions; but felt that he should be very well satisfied if he could construct for himself an orrery to show the motions of the earth and moon, and those of the sun round its axis. This machine he partly constructed with his own hands, and partly with the aid of a turner: and when in action it showed completely the sun's motion round its axis; the diurnal and annual motions of the earth on its inclined axis, which kept its parallelism in its whole course round the sun; the motions and phases of the moon, with the retrograde motion of the nodes of her orbit; and, consequently, all the variety of seasons, the different lengths of days and nights, the new and full moons, and eclipses.

After making a smaller and neater one, with all the wheels of ivory, in May, 1743, he took it to London, where it was bought by Sir Dudley Ryder. Still, he could neither live nor support his wife and three children by the construction of orreries, though he made six, each of which was always more perfect than its predecessor; and had to resort once more to taking miniatures, his chief patron being a Mr. Stephen Poyntz, who resided near St. James's Palace. But astronomy was ever uppermost in his thoughts; and after constructing a very simple machine for describing the paths of the earth and moon in the firmament, he showed it to Mr. Martin Folkes, then President of the Royal Society, who expressed his admiration for the contrivance, and that same evening presented it and Ferguson at a meeting of the society, and thus won him many new friends.

In 1747 he published a dissertation on the phenomena of the harvest-moon, with the description of a new orrery, in which there were only four wheels; but never having had a finished education, nor time to study the rules of composition, he put it to press with extreme doubt and diffidence. On finding, however, that the work was well received, he was encouraged to proceed, and successively issued his "Astronomy," "Mechanical Lectures," "Tables and Tracts relative to Several Arts and Sciences," the "Young Gentleman and Lady's Astronomy," and a treatise on "Electricity."

The year 1748 found him publicly lecturing on these subjects in London, with great success, and also on hydrostatics, hydraulics, pneumatics, and his universal dialling cylinder.

When he had been thirty years in London, he was introduced to the notice of George III., who, when Prince of Wales, had attended his earlier lectures, and who bestowed upon him a pension of £50 per annum; thus by his talents and industry rising from the humblest ranks of the peasantry to become the preceptor of a king.

In 1754 he brought out a brief description of the solar system; but his greatest work is his "Astronomy, explained upon Sir Isaac Newton's Principles, and made easy to those who have not studied Mathematics." His delineation of the complex line of the moon's motion procured him in 1763 the honour of being elected a member of the Royal Society of London, without the payment of the usual fees.

The first edition of his "Dissertation on the Harvest Moon" appeared as early as 1747. His "Easy Introduction to Astronomy" passed rapidly through eight editions in Germany, after its first appearance there in 1771; and Madame Genlis, in her preface to the "Tales of the Castle," remarks that it is a work so perspicuous, that a child only ten years of age may understand it completely. In 1770 he was chosen a member of the American Philosophical Society; and five years afterwards he published "Two Letters to the Reverend John Kennedy, containing an account of many mistakes in the astronomical part of his Scriptural Chronology, and his abusive treatment of astronomical authors."

These were followed by a third letter on the same subject. Some of his writings were translated into French by P. R. Leveque, and they attracted considerable attention among the learned bodies of Paris. The obscurity of his early life, together with the humble situation and indigent circumstances of his father having required that he should—as we have related—engage in the capacity of a shepherd and farm-servant, was the cause of a curious misconception in France, where the astronomer Lalande in his writings speaks of him, in the first volume of his "Astronomie" (page 163), as the "berger du Roi d'Angleterre en Écosse" (the Shepherd to the King of England for Scotland).

By his lectures, his various works, and his frugality, Ferguson amassed a considerable sum; and, ultimately, was enabled to live with ease and comfort in London. The best and most useful work he ever wrote—viz., his "Lectures on Select Subjects in Mechanics, Hydrostatics, etc."—passed through many editions, and has contributed much to the diffusion of mechanical knowledge among all classes of people. A new edition of it, in two vols. 8vo, with an appendix, containing an account of all the more recent inventions and discoveries, was published by the late Sir David Brewster in 1805, and another edition was required in the following year.

His "Select Mechanical Exercises" appeared in 1773; "The Art of Drawing in Perspective" in 1775; and he communicated many papers to the Royal Society, which were published in their "Transactions." Though thus successful in his scientific career, he was not without afflictions in his latter years. His daughter, a girl of great beauty, was unhappily lost to him in her eighteenth year; his eldest son, Murdoch Ferguson, became a surgeon, went to sea, and, by a shipwreck, lost all he possessed. His second son studied physic at the Marischal College of Aberdeen, but nothing more is known of him.

After a long and useful life, this singular man, whose career began as a poor shepherd boy among the Banffshire hills, and "who might be called an enthusiast in his love of God, if religion founded on such substantial and enlightened grounds as his was could be like enthusiasm," died at London, on the 16th of November, 1776, quite worn out by study, age and infirmity.

OBJECT DRAWING.—VIII.

The outline of the group (Fig. 44, page 288) having been thus completed, we proceed with the shading, and it will be seen that in the example the light is placed on the left side and higher than the pyramid; it will therefore be evident that the brightest light will be on the left side of the most prominent angle of the pyramid, and then on the left side of the prominent edge of the oblong block and of the cube. The right-hand side of the whole group will, of course, be shaded. The margin of the base of the pyramid, too, will be in shade, but its tone will be rather darker than that of the sides, whilst the shadow cast on the oblong block by the projecting pyramid, and the cast shadows on the ground and on the upper surface of the cube, will be the darkest of all.

It must be remembered that the most brilliant lights and deepest shadows are those nearest the eye, and that both of these diminish in intensity as their distance from us is increased. In shading, therefore, we must follow this natural effect. Thus, in the present group, the brightest light follows the most prominent angle. The surfaces, however, do not remain equally bright over their whole breadth, but the light gradually tones down as the surface recedes. Similarly, the shade on the right side is darkest where the surface is the most prominent, and the depth of colour is softened down as the distance increases.

This is sometimes called *aërial perspective*, or the perspective appearance caused by the air, for the farther an object or surface is removed from the eye, the greater will be the mass of atmosphere intervening, and thus a sort of medium is formed through which the object is seen more or less distinctly, according to the denseness of the air. Thus, in a clear day, distant objects appear much nearer than they do when the atmosphere is hazy; and this accounts for the sharpness of outline and apparent flatness of objects seen in countries noted for the clearness of the air.

Not only, however, is it found that the lights and shades diminish in intensity as they recede from the eye, but, as a necessary consequence, the contrast between surfaces becomes also less pronounced, and their outlines less distinct, the more the distance is increased. Therefore outlines themselves should vary in the thickness of the lines, and should become fainter and finer as they recede.

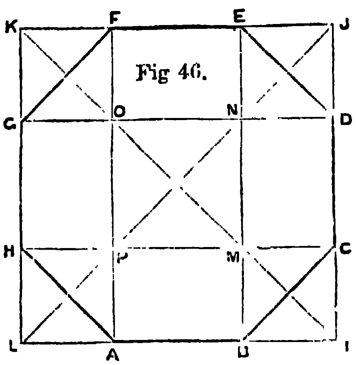
Fig 46.

Fig. 45 represents an octagonal prism.

Before entering on this study it is necessary to preface it by an elementary geometrical construction, in order to show the reason for the disposition of the lines.

Let A B C D E F G H (Fig. 46) be an octagon of which a perspective view is required.

Now, as in the case of circles, it is necessary that polygons should be enclosed in rectangular figures, and the one which will best contain an octagon is the square formed by producing four of its sides—viz., I J K L.

Draw the diagonals I K and L J, also the lines A F, B E, G D, H C, cutting the diagonals in M, N, O, P.

Put the square I J K L into perspective, and draw the diagonals. Set off spaces *l a*, *i b*, as shown in the annexed figure (Fig. 45), corresponding to those lettered L A and I B. From *a* and *b* draw lines to the point of sight, cutting the diagonals in *m*, *n*, *o*, *p*.

Through *m*, *n*, *o*, *p* draw horizontal lines which will cut the sides *i j* and *k l* in *c*, *d*, *g*, *h*. The points *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h* are the angles of the octagon perspectively rendered as lying on the ground-plane with two of its sides parallel, and two at right angles to the picture.

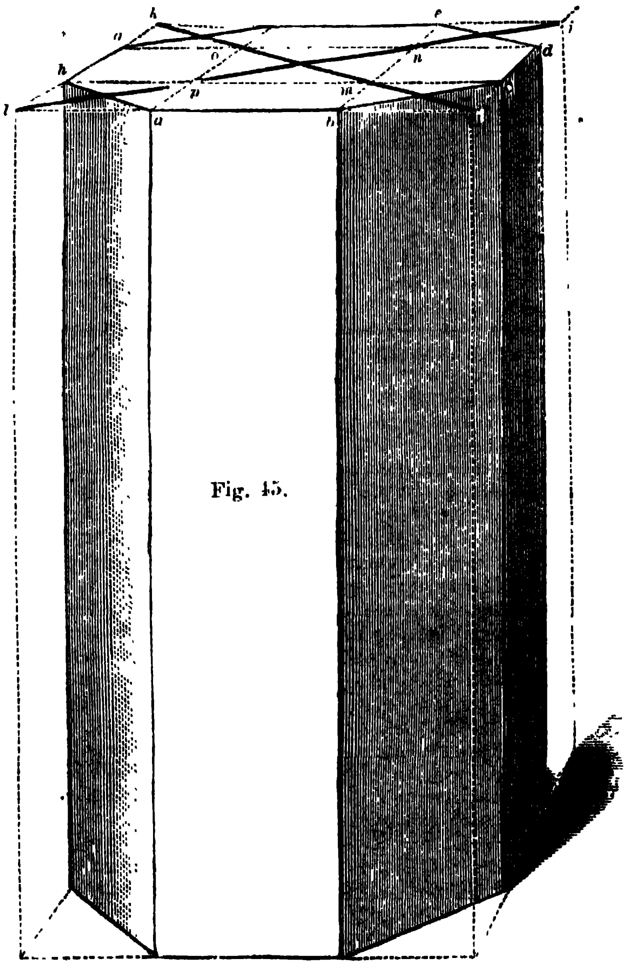
Fig. 45.

Proceeding now with Fig. 45, it will be evident that, if a plane octagon is contained in a square, *an octagonal prism will be contained in a solid oblong* (called geometrically a *parallelopiped*). In commencing, therefore, to draw the object, sketch this oblong, as shown by the dotted lines which are retained to act as guides, but which may be rubbed out in the drawing when the required figure has been correctly delineated.

In the present group it will be evident that the eye of the spectator is on the right-hand side of the objects, and on a higher level.

The student is advised not to place his models exactly like those in the example, but to adopt the principles laid down, instead of copying the drawing. Assuming, however, that he has the exact models, his view will vary according as his eye is above or below, on the left or right of the group; and in determining, therefore, the position of the point of sight he will be guided by the instructions already given. Having, then, sketched the general form of the oblong block, rendering it as if transparent, the perspective representation of the octagon is to be drawn in the figure representing the square top of the block in the manner already shown in the preceding paragraphs of the present lesson.

From the angles of this figure perpendiculars are to be drawn which will cut the base in corresponding points, and these being joined, the view of the octagonal prism will be completed.

The shading of this object in its present position will be found extremely simple, the principles having already been explained. In accordance with these, since the light is supposed to fall on the front and left side of the prism, they will be fully illumined. The darkest shade will be on the right side, which, being a part of the square block in which the octagonal prism is contained, is at 90° to the picture-plane; whilst the side between this and the front being at only 45°, will be of a lighter tint.

The objects represented in the next figures will possess some interest for carpenters and joiners, since they show the method of drawing pieces of wood which are to be "halved" together; a process which has been described in lessons in "Building Construction." Figs. 47 and 48 show the pieces separately. Out of the upper side of the one and the lower side of the other pieces are cut, the recess being in each case as wide as the wood to be sunk into it, and half as deep; and thus, when the pieces are brought together, the thickness at A fills up the depth of B, and the surface C becomes flush with D; a square mortise is cut through both pieces, for a purpose to be subsequently explained.

In drawing these pieces, no notice is, in the first instance, to be taken of the recesses, but the pieces of wood are to be drawn as if complete. The square end of the lower piece is to be drawn first, and from this the long edges converge to the point of sight, in the manner already explained.

On one side of the square mark E, the depth of the recess, and from E draw a line to the point of sight. Then, having marked F and G, draw horizontal lines across the upper surface, and from the extremity of each draw the vertical lines, as at B, as far as the line E. The rest will be easily understood from the illustration.

In Fig. 48, which is parallel to the plane of the picture, the front is, of course, to be drawn first, of its true proportions, but slightly diminished, in consequence of being placed at a short distance back in the picture, so as to be immediately over the middle of Fig. 47. The upper surface and end of this piece will be drawn as in previous cases; and the recess is next to be drawn, care being taken that it corresponds in width with the line at F. The mortise will be easily drawn without further explanation.

The object formed by the union of the pieces will be a cross, which will be the subject of a subsequent study.

Figs. 49 and 50 are two pieces of wood of the same thickness as Figs. 47 and 48, and making together, including the length of the tenon, the same length as the other two pieces. The tenon on Fig. 50 is flat, that on Fig. 49 is square, and has a space equal to one-third of its width cut away; the tenon on Fig. 50 is exactly equal in width to this space, into which it fits; and thus, in making up the length, only one of the tenons is counted. When, therefore, the tenon *a* is inserted into the groove *b* the whole piece becomes the length of Figs. 47 and 48, and its purposes will be shown in a future lesson.

The method of drawing these two pieces is precisely the same as that already shown, and therefore no further explana-

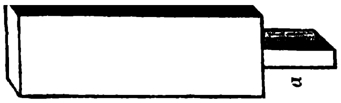

Fig. 50.

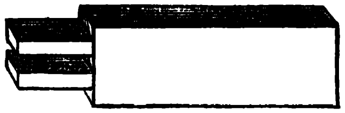

Fig. 49.

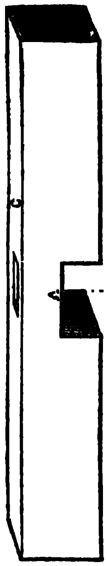

Fig. 48.

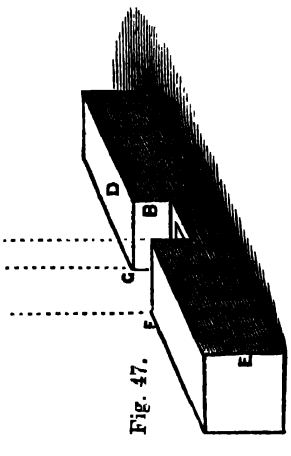

Fig. 47.

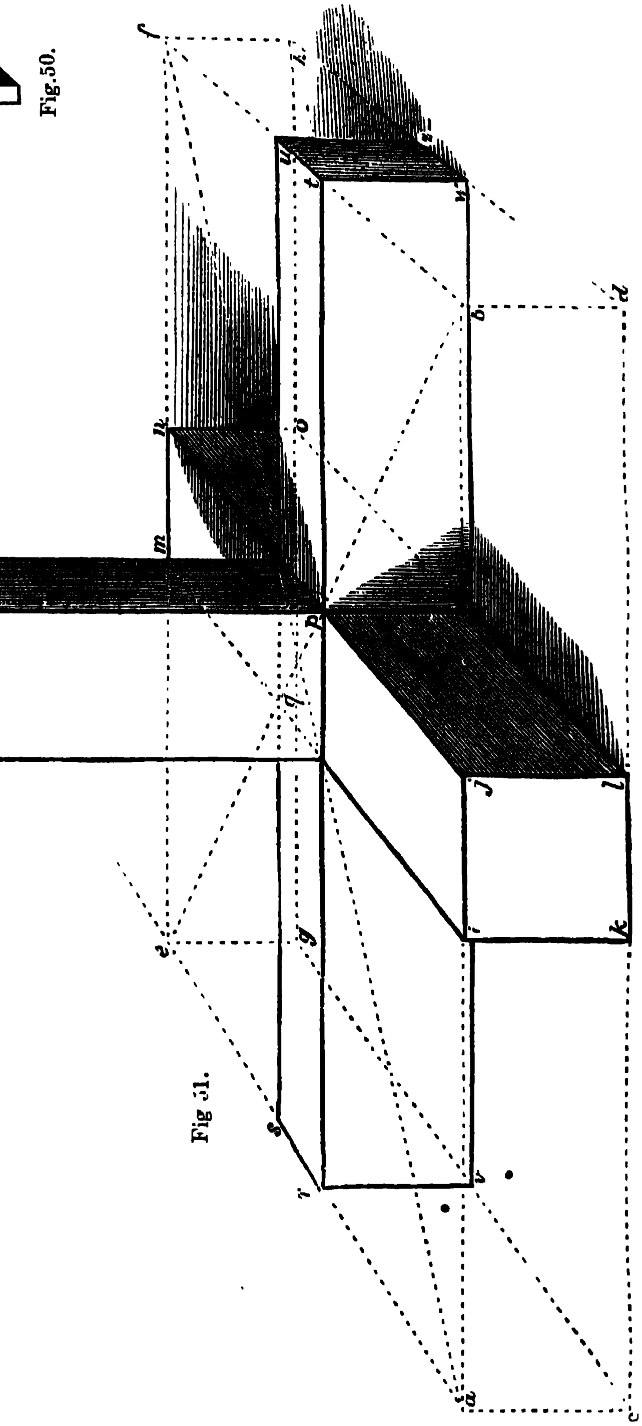

Fig. 51.

Fig. 51 shows the cross lying horizontally, and serving as a stand for an upright. This construction is used for a variety of purposes that will readily suggest themselves.

Now it is clear that a cross having four equal arms would be contained in a square slab, and this knowledge shows us the most simple method for drawing the object.

Let *a b d c* be the front edge of such a slab, its length and thickness being those of the wood of which the cross is made.

Complete the view of the block, rendering it as if transparent.

Now, in the middle of the rectangle *a b d c* draw the square *i j l k* for the end of the one bar which is at right angles to the plane of the picture, and from the angles draw lines to point of sight, meeting the distant side of the slab in *m*, *n*, *o*; lines joining these points will complete this bar.

Draw the diagonal *b c*, which will cut the lines *j n* and *i m* in *p* and *q*.

Through *p* and *q* draw horizontal lines, which meeting *a c* in *r*, *s*, and *b f* in *t*, *u*, will give the upper surface of the second bar of the cross. From *p* draw a perpendicular to meet the line *l o*, and this will give the point through which the line *v w* is to be drawn; the lines *r v*, *t w*, and *u z* will then complete the view of the cross.

Now at the points of junction of the two bars raise perpendiculars, and finish the upright, as in Fig. 50.

The shading of this object is exceedingly simple, and will be readily understood on reference to the illustration.

NOTABLE INVENTIONS AND INVENTORS.

XX.—GLASS-MAKING (*continued*).

BY JOHN TIMBS.

A SQUARE solid pedestal of yellow-tinged glass is preserved in the Museum of Economic Geology, in Jermyn Street; it is surmounted by a small lion, carved by the engraver's mandril-tool, at the lathe, at great labour and cost. This was probably made from English glass, re-fused in China with an increased quality of lead. Small coloured vases, figures, and almost every description of ornament sculptured in stone, have been imitated in opaque glass by the Chinese. Yet they neglect the manufacture of useful articles of glass, and re-melt broken glass from Europe for such articles as they require. The Emperor has a royal glass manufacture in Pekin, though it is carried on as much for amusement as for utility.

Glass engraving in its modern acceptation—viz., roughed and polished in intaglio—was, probably, unknown to the Romans and their predecessors. The art of cutting glass in relief was, however, known to them at a very remote period; for which purpose, as we learn from Pliny, the diamond was used.*

Pictures were formed by the ancients laying together fibres of glass of various colours, fitted to each other so exactly, that a section across the fibres represented the object to be painted; and was then cemented by fusion into a homogeneous, solid mass. In some specimens discovered in the middle of the last century the pieces had been so accurately united by intense heat, that not even by means of a powerful magnifying glass could the junctures be discovered. One small fragment, in the British Museum, exhibits an arabesque border of various colours, the outlines of which are well divided and sharp, and the colours pure and vivid; whilst a brilliant effect has been obtained in another piece by the artist employing in contrast opaque and transparent glasses. The pictures appear to be continued throughout the whole thickness of the specimen, as the reverses correspond in the minutest points to the face; so that were the glass to be cut transversely, the same arabesque border would be found exhibited on every section. It is conjectured that this curious process was the first attempt of the ancients to preserve colours by fusing them into the internal parts of the glass. In the British Museum are many of these interesting curiosities of glass mosaic work, some of perfectly white clear glass, in leaves or flowers, on a dark-green ground; most of the pieces are small, and the patterns very minute. There are also numbers of fragments of white enamel upon blue, and white upon amethyst grounds, well executed in relief; probably the work of eminent Roman or Greek artists resident in Rome.

In the British Museum there are a few large cinerary urns of green glass, which are fine specimens of the ancient art of glass-blowing. The round vases are of elegant form, with covers and two double handles, showing that the ancients were well acquainted with the art of making round glass vessels. The most celebrated ancient glass vase is that which was for more than two centuries the principal ornament of the Barberini palace, and which is now known as the Portland vase. It was found about 1560, in a sarcophagus under the Monte del Grano, two miles and a half from Rome, on the road to Frascati. It was deposited in the palace of the Barberini family until 1770, when it was purchased by Byres, the antiquary, and sold by him to Sir William Hamilton, of whom it was bought, for 1,800 guineas, by the Duchess of Portland, at the sale of whose property it was bought in by the family for £1,029. The vase is 9¾ inches high and 7¼ inches in diameter, and has two handles. It is of glass: yet Breval considered it chalcedony; Bartoli, sardonyx; Count Tetzi, amethyst; and De la Chausse, agate. It is ornamented with white opaque figures upon a dark-blue semi-transparent ground; the whole having been originally covered with white enamel, out of which the figures have been cut, like a cameo. The glass foot is distinct, and is thought to have been cemented on after bones or ashes had been placed in the vase. The seven figures, each five inches high, are said by some to illustrate the fable of Thaddeus and Theseus; by Bartoli, Proserpine and Pluto; by Winckelmann, the nuptials of Thetis and Peleus; Darwin, an allegory of Life and Immortality; others, Orpheus and Eurydice; Fosbroke, a marriage, death, and second marriage; Tetzi, the birth of Alexander Severus, whose cinerary urn the vase is thought to be; while Mr. Windus, F.S.A., in a work published 1845, considers the scene as a love-sick lady consulting Galen. The vase was engraved by Cipriani and Bartolozzi in 1786: copies of it were executed by Wedgwood, and sold at fifty guineas each, the model for which cost 500 guineas; there is a copy in the British and Mediæval Room.

The Portland vase, February 7, 1845, was wantonly dashed to pieces with a stone; but the pieces being gathered up, the vase has been restored by Mr. Doubleday so beautifully, that a blemish can scarcely be detected. A drawing of the fractured pieces is preserved.

This beautiful work of art affords satisfactory proof that the manufacture of glass was carried to a state of high perfection by the ancients. Sir Joseph Banks and Sir Joshua Reynolds bore testimony to the admirable execution of Wedgwood's copies of the vase, which were chased by a steel rifle after the bas-relief had been wholly or partially fired.

Venice, during a long period, excelled all Europe in the fineness of its glass. In the thirteenth century the processes of the Phœnicians seem to have been learnt by the Crusaders, and transferred to Venice and the neighbouring island of Murano, where they were long held secret, and formed a lucrative commercial monopoly. The old Venetian blown glass was light, bright, vitreous in appearance, stained with the richest possible colours. Some of the particular secrets of this manufacture have been handed down from father to son, and so carefully treasured up, that at this very day, quite as much as in the age of Marco Polo, Venice possesses the absolute monopoly of the art; and lineal descendants of the old Venetian glass manufacturers still inhabit the island of Murano.

The revival of the ancient art of glass-blowing is due to Dr. Salviati, whose imitations of the old Venetian *soffiati* and execution of new designs are most successful. The *soffiati*, or blown glass, produced by Dr. Salviati, equal, and even surpass, the old in lightness, brilliancy, colour, and design. The glass-blowers of Murano are now able to produce nearly all the famous kinds of ware so peculiar to Venetian glass.

First, and most characteristic, of the Venetian varieties is the *Laticinio* or filigree glass, with coloured threads, generally in opaque milk-white; hence the name *Laticinio*. In some specimens the threads form lacework glass, or *Vitro di Trino*. The *reticello* is produced by a kind of network, consisting of small bubbles of air inclosed within the mass, and arranged in a regular series, crossing and interlacing each other. The *filigree* glass is produced by using rods which contain threads of white or coloured enamel in a body of clear glass. The *millefiore* consists of a mass of clear white crystal, inside of which and embodied in it are representations in coloured glass of coral flowers, and is formed by laying together fibres of glass of various colours. Winckelmann describes a similar art of the ancients. The *ritorto*, or twisted patterns, or many coloured glass rods, are fused together with clear glass. *Schmelze* is a semi-opaque glass, of a richly variegated brown, green, or blue; and *Avanturine*, with metallic filings of levigated leaf gold suspended in it, is said to have had its origin in a workman having accidentally let fall some brass filings into a crucible of melted glass, whence both the process and the term.

The celebrated frosted or "crackle" glass of the Venetians was long considered a lost art; it is made by suddenly plunging the hot glass into cold water, and in this manner fractures are produced of a crystalline character. The glass is then re-heated at the furnace, and the heated ball is afterwards expanded by blowing. Although frosted glass appears covered with fractures, it is perfectly sonorous.

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* To Dr. Wollaston are we indebted for this explanation of *how the diamond cuts glass*. He ascertained that the parts of the glass to which the diamond is applied are forced asunder, as by a wedge, to a most minute distance without being removed, so that a superficial, continuous crack is made from one end of the intended cut to the other. After this, any small force applied to one extremity is sufficient to extend this crack through all the whole substance, and across the glass; for since the strain at each instant in the progress of the crack is confined nearly to a mathematical point at the bottom of the figure, the effort necessary for carrying it through is proportionally small. Dr. Wollaston found by trial that the cut caused by the mere passage of the diamond need not penetrate so much as the two-hundredth part of an inch. He found also that other mineral bodies recently ground into the same form, are also capable of cutting glass, but they cannot long retain that power, from want of the requisite hardness.

Coke possesses one of the remarkable properties of the diamond—that of cutting glass so clean and perfect as to exhibit the most beautiful prismatic colour, according to the perfection of the incision.

The Venetians, besides discovering the art of rendering glass colourless by means of manganese, also enjoyed the monopoly of mirrors, the silvering of which was a secret long kept from other countries; but foreign competitors now produce larger plates.

Venice still possesses the absolute monopoly of the art of bead-making; and great impetus has been given to the bead trade by the prevailing fashion of black beads, for which there is a great demand; as also for glass bugles, of which vast quantities are sold for the African and other foreign markets. The manufacture is divided into common glass beads and enamel beads. The furnaces are built of fire-clay. The materials are vitrified in pots, the principal ingredients for glass beads being Nola sand, Catania soda, natron, antimony, arsenic, manganese, minium, nitre, etc. The materials for enamel beads are almost every product of the mineral kingdom; gold and silver being used in considerable quantities. The Venetians are still in possession of the best enamel processes—the inlaid or marqueterie mosaics produced by all the enamel pieces perfectly united, generally used for ear-rings, bracelets, etc. The Florentine mosaics are made up of stones; the Roman of thin pieces of enamel; and the monumental or Byzantine is most fitted for architectural decorations. In England, fine specimens of modern Venetian mosaics may be seen at the South Kensington Museum, and St. Paul's Cathedral, London. The vaulted roof of the Wolsey Chapel, at Windsor, represents the kings and queens of England in mosaic, and Dr. Salviati is executing mosaics for the national memorial to the late Prince Consort, now in the course of erection in Hyde Park. Enamels are much more permanent than any other substance that has been used in the composition of mosaic, whether stone, marble, or clay, on account of their less porous and less dilatable body.

Gold and silver enamels are now used with improved effect in monumental mosaics, in which the gold or silver is attached to the glass by the action of fire, and the three layers being fired together, form a homogeneous body, which serves to protect the metal for ever against all injury, either by atmospheric action, dust, gas, smoke, or insects, so as not to lose any of its brilliancy or colour, even after many centuries of exposure.

The manufacture of glass was probably introduced into France at the same date as into Germany. Both countries derived their knowledge of it from the Romans; or, probably, from their commercial intercourse with the East, improved by the Romans, and still further advanced in quality and artistic ornamentation, adopted from the Venetians. Later, France sought to increase the supply of her own demands. Her government early decreed that none but gentlemen should engage in any of its branches; and late in the seventeenth century the French glass-blower might be seen laying aside his cocked hat, dress-coat, and sword, to prepare for his daily work.

MINING AND QUARRYING.—XII.

BY GEORGE GLADSTONE, F.C.S.

IRON.

ROLLING—PUDDLED BAR—FINISHING—PROPERTIES OF IRON—GALVANISED IRON—EFFECT OF TIN AND COPPER—NATURAL AND ARTIFICIAL SALTS OF IRON—THEIR USES.

THE final steps in the manufacture of malleable iron consist in rolling, for which purpose there are required two series of rolls, the *roughing* and the *finishing*.

They consist of cylinders of hard iron working in pairs, the grooves in the upper corresponding exactly with those of the lower, as shown in Fig. 17. The latter are turned by a crank connected with the shaft A A, and the upper series necessarily revolve in the opposite direction at the same rate, being driven by the cog-wheels B, B. The space between the cylinders can be slightly modified by turning the screws C C, which connect, through the bearers, with the upper rolls. The "bloom," or hammered ball, while yet hot, is held by a pair of tongs, and pressed by the first workman against the largest groove in the rolls, which, as they revolve, draw it in between them, the surface of the grooves being slightly roughed by scorings like those of a file, so as to take firm hold of the iron. It thus becomes elongated, and takes the form of a rod. The second workman, on the other side of the rolls, lays hold of it, as it passes through, with another pair of tongs, and hands it back again, and so on until the iron has passed through the whole set of grooves, down to the smallest. When it has gone under the flat rolls it takes the form of a flattened bar of iron, and is known by the name of "puddled bar."

The processes of hammering and squeezing, described in the last article, and the subsequent rolling, have still further improved the quality of the iron, though again at the expense of quantity. The sample of iron which was described in detail in Article X., and contained at the end of the puddling 0·772 per cent. of carbon, and 0·168 per cent. of silicon, contained, after rolling, only 0·296 per cent. of the former, and 0·120 per cent. of the latter. The hammer slag or mill scale which comes off during these processes contains, however, a good deal of iron, and is of value in puddling, so that the metal is not ultimately lost. It consists, indeed, entirely of the protoxide and sesquioxide, containing 70 to 75 per cent. of metallic iron.

Puddled bar is still capable of improvement; and for making the best descriptions of iron it is cut up into short lengths by means of massive shears driven by steam, made up into piles or fagots, and then put into the re-heating furnace, after which it is again rolled. This operation is repeated as often as may be desired; the more the iron is worked in this way the better being the fibre. The piles are sometimes made by laying the alternate pieces of iron crosswise, the intertwining of the fibre being supposed to be more complete when this is done. At other times an inferior quality of iron is put in the middle of the fagot, so that when rolled out again the exterior of the bar shall be of superior strength to the interior; this is not unfrequently done as a matter of economy in the manufacture of railway bars, as the principal wear and tear is upon the head of the rail, and there is no occasion to waste the best iron upon those parts which are sure to outlast the upper surface.

The re-heating furnace is constructed on the reverberatory principle, and coal is generally used as the fuel. The hearth upon which the fagots are laid is made of sand, and slopes down towards the flue, so that whatever iron passes into combination with the silicon shall at once flow down to the tap-hole. The air is excluded as far as possible, so as to prevent oxidation, and the iron is taken out immediately it has arrived at a welding heat. It is then in that sticky stage so peculiar to iron, which renders it so easy of manipulation, and on passing through the rollers the several pieces become perfectly united.

The finishing rolls, which are now used, are quite smooth, and the groovings in them are made to conform more and more to the size and form which the iron is ultimately to assume, until the last pair of grooves will turn it out of the precise pattern required. In this way all the different forms and sizes of merchant iron - bar, rod, sheet, rails of various patterns, T and angle iron, etc.—are produced. The rate at which the rolls are driven varies very greatly according to the nature of the work in hand; for ordinary purposes, sixty to eighty revolutions per minute will be made, so that the iron has passed through the whole series of grooves, and comes out finished before it has had time to cool. The cylinders themselves are supplied with a little stream of cold water, in order to prevent them from becoming overheated.

As illustrations of what different kinds of work are done by the rolling mills, we may refer to "slit rods," which are used for nail-making and such-like purposes. In the slitting mill a thin bar of iron is at once cut into a number of very narrow slips, the one roller having deep and narrow grooves very close together, and the other collars to correspond, made with sharp cutting edges. By way of contrast, let us now take the manufacture of armour plates. They are sometimes made in the forge, but at other works they are rolled out. Instead of a strip, a quarter of an inch or less in diameter, the rolls have now to turn out a plate of iron perhaps twelve inches thick and some six feet wide, weighing many tons. Such plates have been turned out at the works of John Brown and Co. (Limited), at Sheffield, where the armour for many of our iron-clad floating batteries has been made. The process employed is essentially what has been already described, but the difficulty of the operation increases with the accumulation of mass, as it is difficult, even with the most powerful machinery, to bring sufficient force to bear to weld the component pieces perfectly together.

The workmanship is, however, so good, that on the edges being planed there are no indications to the eye of any want of coherence.

The peculiar property of iron called "welding" has not, however, yet received all the consideration it deserves. It has been mentioned in the manufacture of the better qualities of finished iron, and the making of all large pieces of rolled iron is absolutely dependent upon it. Equally so is this the case in making large forgings. Some of the largest armour plates have been forged with the steam-hammer, one of thirteen tons weight made in this way having been on view at the International Exhibition of 1862. These are built up of separate pieces of iron raised in the furnace to a welding heat, and then hammered into one solid mass. This is an operation which cannot be accomplished with any other of the useful metals, and is principally due to the circumstance that iron (unlike all the rest), when heated, does not pass suddenly into the molten state, but after becoming red hot, at which stage it commences to soften sufficiently to yield to the hammer, can be raised to a much higher temperature and almost to a white heat without melting. At this stage the presence of a little flux will remove any oxide that would otherwise form on the surface of the iron; and the metal itself being then in a pasty or sticky condition, the clean surfaces of any pieces coming in contact will readily adhere to one another, while by pressure or hammering they may be brought into absolute contact throughout, their mass forming a single piece of solid iron.

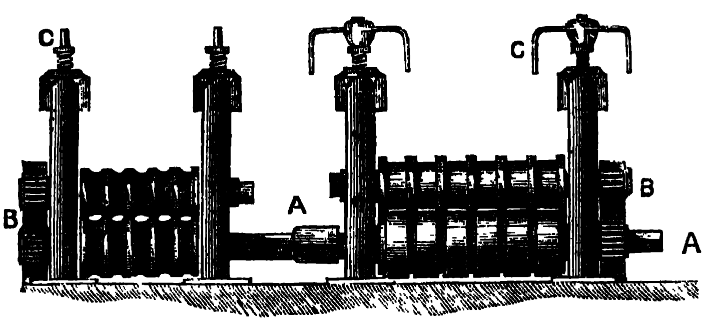

Fig. 17.

The shafts of marine engines and all other large pieces of machinery which have to bear much strain, must be forged, not cast. That of the *Great Eastern* weighs something more than thirty-one tons, made up of bars welded together under the steam-hammer. Cast iron, in cooling, takes an irregular crystalline form, and the parts do not cohere with any great tenacity, so that all the products of the foundry are comparatively brittle. The finishing processes impart fibre to the iron, by which its strength is very greatly increased. The difference in the structure of the iron is very different when broken, the one breaking off short and presenting a granular appearance, while the other is more or less drawn out into threads. This is one of the best tests that can be applied, and it is therefore constantly adopted. If the iron is of the very finest quality, a thick round bar of it may be tied into a knot when cold without breaking, whereas an inferior iron is certain to give way. Hammering iron when cold is believed to have the opposite effect, and the sudden breaking of iron after having been subjected to a jarring or vibrating action for a long time, is considered by some to be due to a molecular change in the particles of the iron. The brittleness of iron during extreme cold weather is probably to be attributed rather to the unequal construction of the parts most exposed.

Iron suffers under one disadvantage more than almost any other metal—viz., the tendency to rust. Whenever exposed to the influence of a moist atmosphere, an oxidation of the surface is sure to take place, and the iron commences to be eaten away. When once this action has set in it is difficult to arrest its progress altogether, and therefore, wherever possible, the ironwork should be coated with paint, or some other article impervious to the air, without delay. Those portions of machinery which must necessarily be kept bright are best protected by being carefully smeared with grease.

It has been found, however, that zinc has the property of retarding the oxidation of iron, and this has led to a very extensive manufacture of what is called "galvanised iron," which has recently been largely employed for roofing purposes. The iron is rolled out into thin sheets, and the surface is thoroughly cleaned by being exposed to the action of a weak acid and then washed, when it is said to be "pickled," after which it is immersed in a bath of melted zinc to which some ammonia is added. On withdrawing the sheets of iron after a time from the bath, a thin layer of zinc will be found adherent to the entire surface, which has so combined with the iron that it cannot be again removed. Iron wire rope for the rigging of ships, etc., chains, and other articles much exposed to the influences of the weather, are very often coated with zinc in the same way.

Both tin and copper seem to exercise an opposite effect. It will be familiar to most housewives how rapidly a tin plate will be covered with spots of rust wherever the coating of tin has been accidentally removed and the iron which forms the foundation becomes exposed to the air. A further description of tinned iron will be given when we come to speak of the reduction and uses of tin, the latter being the metal which imparts to these plates their principal value. The effect of copper upon iron, especially in the presence of sea-water, is so marked, that copper sheathing cannot be applied to an iron vessel, and even in the highest classed wooden ships iron bolts are not allowed to be used below the level of the coppering. Iron vessels, which are now becoming such great favourites (especially in the steam trade), have, therefore, to be coated with some paint or varnish; but as yet no compound has been hit upon which satisfactorily fulfils all the purposes desired.

It seems hardly right to leave the subject of iron, which has now been traced from its ores through all its varied stages up to the manufactured article, without referring to sundry chemical compounds of iron, both natural and artificial, which are of much value in the arts.

Sulphide of iron is a very common mineral, frequently called iron pyrites, which is principally wrought for the sake of the sulphur and not the iron; and as to which it will therefore be sufficient to refer the reader to the article on the manufacture of sulphuric acid ("Chemistry applied to the Arts," No. XI.).

The red and brown hæmatites (the anhydrous and the hydrated sesquioxides of iron) have been incidentally mentioned as furnishing rouge and ochre respectively. The latter is an article of some commercial importance. Chrome iron ore is also principally valuable as the source of chromic acid, which enters largely into the composition of yellow paints and dyes. There are also various ores of iron of which the other ingredients form the most important feature, and which will have to be referred to when treating of the respective metals.

The artificial compounds of iron are of considerable importance in the arts. There is the sulphate, more generally known under the name of copperas or green vitriol, which is made by dissolving iron filings in dilute sulphuric acid, and then evaporating the solution down until the salt crystallises out; or as a bye-product in the manufacture of alum, which is the ordinary commercial article. It is largely used in dyeing black and in making black ink, that colour being produced by the action of this salt upon any article containing tannic or gallic acid.

Iron also enters into the composition of Prussian blue (ferrocyanide of iron), and into the yellow and red prussiates of potash, all of which are largely used by dyers. Acetate of iron is also employed for producing a deep black colour with madder. It is prepared by dissolving small pieces of iron in warm acetic acid.

The use of iron in medicine is also fully recognised. Various artificial combinations of it are in constant use in pharmacy, some two dozen different preparations of this metal appearing in the Pharmacopœia; besides which, it is drunk largely in mineral waters, all the chalybeated and many of the other celebrated springs of this country and the Continent containing notable quantities of the salts of iron.

We have reserved for the next article all reference to a very important modification of iron, steel being a subject of sufficient magnitude to be treated separately, and which has characteristics of its own which will come out more clearly by being considered as a distinct subject.